

EVALUATE THE DEGREE TO WHICH THE PRELIMINARY FINDINGS ON THE FAILURE OF THE LEVEES ARE BEING INCORPORATED INTO THE RESTORATION OF HURRICANE PROTECTION

HEARING

BEFORE THE

**COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE**

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

November 17, 2005

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ONE HUNDRED NINTH CONGRESS
FIRST SESSION

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EVALUATE THE DEGREE TO WHICH THE PRELIMINARY FINDINGS ON THE FAILURE OF THE LEVEES ARE BEING INCORPORATED INTO THE RESTORATION OF HURRICANE PROTECTION

THURSDAY, NOVEMBER 17, 2005

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The committee met, pursuant to notice, at 9:30 a.m. in room 406, Senate Dirksen Building, Hon. James Inhofe (chairman of the committee) presiding.

Present: Senators Inhofe, Bond, Thune, Isakson, Vitter, Jeffords, and Carper.

**OPENING STATEMENT OF HON. JAMES M. INHOFE,
U.S. SENATOR FROM THE STATE OF OKLAHOMA**

Senator INHOFE. Good morning and welcome to our fourth full committee hearing on the response to Hurricanes Katrina and Rita. Our first two hearings focused on the Federal response to the hurricanes and our most recent hearing considered some steps required to bring into focus the degree to which the preliminary findings on the failure of the levees are being incorporated into the restoration of hurricane protection in Louisiana. Repairs to the levee system must begin now in order to prepare for the next hurricane season, which means that we can't wait for final reports to begin the rebuilding.

Conversely, if preliminary findings suggest areas of weakness in levee design or construction, it is important to incorporate those preliminary findings in near-term restoration efforts. The challenge we have at hand is incorporated in the lessons learned from the ongoing assessment of levee performance, while simultaneously restoring the levee system to pre-hurricane design.

So I thank all of you for coming today. Senator Jeffords, we had said as soon as we get 6 Members here, we will probably take up these amendments and then of course, we will have to have 10 for, I think we have 5 final passages on resolutions. So we may have to do that off the floor during a vote, perhaps.

[The prepared statement of Senator Inhofe follows:]

STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE
STATE OF OKLAHOMA

Good morning and welcome to our fourth full committee hearing on the response to Hurricanes Katrina and Rita. Our first two hearings focused on the Federal response to the hurricanes and our most recent hearing considered some steps required to develop a comprehensive plan for Coastal Louisiana, including storm protection, navigation and wetlands restoration. Today, we will evaluate the degree to which the preliminary findings on the performance of the levees are being incorporated into the restoration of hurricane protection.

I want to thank all of our witnesses for coming today and participating in this committee's ongoing and comprehensive review of hurricane response and recovery. I appreciate your willingness to travel here, and I look forward to hearing from you.

Before we get too far down the road of deciding what we should do when rebuilding, we first must understand happened to the levees and why the city was flooded. If mistakes were made in the past, they must be rectified. There are a number of experts here today that have been taking a look at this very issue, and while it is too early for final conclusions, some preliminary assessments have already been made. I understand that the Army Corps of Engineers has been making some adjustments when restoring the current protection to take into account these initial findings.

This hearing is especially important in that it will help bring into focus the degree to which the preliminary findings on the failure of the levees are being incorporated into the restoration of hurricane protection in Louisiana. Repairs to the levee system must begin now in order to prepare for the next hurricane season, which means that we can't wait for the final reports to begin the rebuilding. Conversely, if preliminary findings suggest areas of weakness in levee design or construction, it is important to incorporate those preliminary findings in near-term restoration efforts. The challenge we have at hand is incorporating the lessons learned from the ongoing assessment of levee performance while simultaneously restoring the levee system to pre-hurricane design standards.

Once again, thank you all for coming today. I look forward to working with all of you and my colleagues on the EPW Committee to ensure that we restore hurricane protection to Louisiana in an effective and responsible manner.

Senator INHOFE. Senator Jeffords.

**OPENING STATEMENT OF HON. JAMES M. JEFFORDS,
U.S. SENATOR FROM THE STATE OF VERMONT**

Senator JEFFORDS. Good morning, Mr. Chairman. I am pleased to once again be here to receive testimony regarding the reconstruction of the flood control system in the wake of Hurricane Katrina. Today we will hear from the Army Corps of Engineers and multiple experts regarding the rebuilding of the levees and whether or not the Corps is considering the preliminary information regarding levee failures as it rebuilds New Orleans.

Last week, I said that without adequate flood control, redevelopment will be impossible. It is imperative that as we try to rebuild flood control quickly, in preparation for another hurricane season, we do not build a fatally flawed system that could further erode public confidence and slow redevelopment. It is part of this committee's responsibility, as the committee jurisdiction for the Army Corps, to ensure that water resources are a positive force in the redevelopment of New Orleans, not a hurdle to overcome.

Today's hearing will, I hope, identify what needs to be done to ensure that an initial rebuild is effective. That will be the first step in what should be a comprehensive, integrated water resources plan to provide protection and restore ecosystems.

Thank you.

[The prepared statement of Senator Jeffords follows:]

STATEMENT OF HON. JAMES M. JEFFORDS, U.S. SENATOR FROM THE
STATE OF VERMONT

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Today's hearing will, I hope, identify what needs to be done to ensure that our initial rebuild is effective. That will be the first step in what should be a comprehensive, integrated water resources plan to provide flood protection and restore ecosystems.

Senator INHOFE. Thank you, Senator Jeffords.

We will have to have six Members, but we also have to have two Democrats, so we will wait until a Democrat comes in, and we may interrupt our opening statements at that point to handle one of the business items that will be necessary.

Senator Vitter.

**OPENING STATEMENT OF HON. DAVID VITTER, U.S. SENATOR
FROM THE STATE OF LOUISIANA**

Senator VITTER. Thank you, Mr. Chairman and Ranking Member Jeffords, for having this hearing. It is very important. I had requested this hearing because it is so important to understand exactly why the levee system failed in the greater New Orleans area during Hurricane Katrina. It is important to understand that so we move forward in the right way, not just rebuilding levees and floodwalls, but making sure we rebuild them right, so they provide a solid foundation of protection for the next hurricane season.

Before Hurricane Katrina, an estimated two-thirds of the entire population of Louisiana lived in the areas now declared disaster areas. Those folks, many of them are still deciding whether or not to return home. Restoration of the hurricane protection system and assurance that we will use a better, smarter design and build more protection is absolutely crucial to allowing those people and businesses and investors to return home.

Today, I look forward to hearing from the Army Corps of Engineers and other independent teams about the preliminary findings from their investigations and the levee system's performance during Hurricane Katrina. I want to thank all of those witnesses for being here today and for their important ongoing work.

Preliminary findings seem to show that there is a problem when rebuilding the levees and floodwalls are done with different designs. For instance, the transition points in the protection system between different types of designs for levees and floodwalls actually weakened the structure. For this reason, we must not rebuild only in areas of the system that had a failure, because first, it won't address the fundamental design problems with the other parts of the system that happened not to fail, but were designed the same way. Second, it is actually multiplying the transition points between dif-

ferent types of systems. Again, those transition points are points of weaknesses.

So there needs to be consistency in the design of the levees and floodwalls to make sure we do not have failures again. Of course, that is the whole point, we must make sure that this devastation, which has caused tremendous heartache and misery and loss on the ground and tremendous cost to the Federal Treasury never happens again.

We need stronger, improved hurricane protection now. Rebuilding to just pre-Katrina conditions isn't an option. When we say to Louisianans, we have a Category 3 protection system in place, we need to be certain that we have a true Category 3 protection system in place. I certainly hope that is the goal for the next hurricane season, and then to go beyond with an intelligent design of a higher standard of protection.

So thank you very much, Mr. Chairman and Ranking Member, for this hearing.

[The prepared statement of Senator Vitter follows:]

STATEMENT OF HON. DAVID VITTER, U.S. SENATOR FROM THE STATE OF LOUISIANA

Thank you Chairman Inhofe and Ranking Member Jeffords for holding this hearing today. I requested that the Environment and Public Works Committee hold this hearing because it is very important to understand what caused the levee system to fail during Hurricane Katrina so that these factors can be incorporated in making the levees better and stronger so they will withstand future storms. This time we need to not just rebuild the levees and floodwalls, but rebuild them right so they provide a solid foundation of protection for the next hurricane season.

Before Hurricane Katrina, an estimated two-thirds of the population of Louisiana lived in the areas now declared disaster areas. Louisianans are still deciding whether or not to return home. Restoration of hurricane protection that incorporates better, smarter designs is a key factor for people and businesses when deciding whether or not to return to Louisiana.

The city of New Orleans and the surrounding parishes are below sea level. Once the storm surge overwhelmed the levee and floodwalls system, the Greater New Orleans area had extensive flooding. For several weeks, the areas remained flooded. Many Louisianans lost their homes and over 1,100 lives were lost. This is why stronger hurricane protection must be put in place by the next hurricane season to ensure it is safe for Louisianans to return home and as they rebuild their lives in Louisiana.

Today, I look forward to hearing from the Army Corps of Engineers and other independent teams about the preliminary findings from their investigations of the levee system's performance during Hurricane Katrina. I would like to thank the witnesses for testifying before the committee today and providing critical information from their investigations that will be important toward the effort in restoring stronger hurricane protection in Louisiana.

From hearing the witness's testimony today, we will have a better understanding of whether the failure in our protection system was due to geological considerations, overtopping, other design problems, or other causes. In order to provide a stronger level and smarter design for hurricane protection in Louisiana, it is important that we understand how faults occurred in the system and what designs need improvement. It is also important to recognize that these failures in the system could happen in other areas along the hurricane protection system too. We need to be certain that those areas of the system that did not fail during Hurricane Katrina are not at risk of failing during future storms.

Preliminary findings show that there is a problem when rebuilding the levees and floodwalls with different designs. The transition points in the protection system between different types of designs for levees and floodwalls actually weaken the structure. For this reason, we should not rebuild only areas of the system that had a failure because it will not address the fundamental design problem within the entire hurricane protection system. There needs to be consistency in the design of the levees and floodwalls otherwise if only the levees that failed are rebuilt with better designs for stronger protection, the rest of the levee and floodwall system will just weaken the entire structure and protection system. Obviously, it is necessary that

all of these areas of the system are upgraded with better designs that guarantee stronger hurricane protection.

We must make sure this devastation never happens again. We need stronger, improved hurricane protection now. Rebuilding to just “pre-Katrina” conditions is not an option. When we say to Louisianans that we have a Category 3 hurricane protection system in place, we need to be certain that we truly mean we have a true Category 3 protection system in place. We need a strong foundation on which to build upon in the future. Therefore, we need a true standard of hurricane protection now that provides a solid, consistent, strong level of protection throughout the entire system.

Thank you.

Senator INHOFE. Thank you, Senator Vitter.

Senator Isakson is here for an opening remark. But you also might mention, we are going to be asking unanimous consent when we have the appropriate number here to include yours on the agenda, since we didn’t have the time to do it in the normal way, as we discussed yesterday. So you might, while we are waiting for another person to come, go ahead with your opening statement, then we will recognize you to explain that, so that we will be ready when the appropriate time comes.

**OPENING STATEMENT OF HON. JOHNNY ISAKSON,
U.S. SENATOR FROM THE STATE OF GEORGIA**

Senator ISAKSON. As far as an opening statement is concerned, I want to really commend Senator Vitter for the hard work that he’s undertaken in this committee since the tragedy of Katrina to really dig down and find out the facts, so we do not repeat mistakes of the past that were made, not intentionally, but we have learned from since Katrina. I sincerely hope we will continue as a Senate to learn from what we learn of the past, and build constructively in the future, so as to avoid those breaches or anything that might have contributed to those breaches.

But not to get into a blame game of historically what happened in the past, but instead a learning experience so we can do it right in the future. I commend Senator Vitter for his efforts in that regard, and I look forward to working with him and the Members of the committee with regard to the levees in New Orleans and their reconstruction.

Would you like for me to go into the—

Senator INHOFE. Yes, why don’t you just briefly, and then we will be ready for that.

Senator ISAKSON. Mr. Chairman, I was asked by a dear friend of mine, Dr. Sullivan, the former Secretary of Health and Human Services in the Bush I administration, to shepherd a piece of legislation in the Senate dealing with the land transfer of currently Government-owned property on Independence to the National Health Museum, which is a private, not-for-profit, 501(c)(3), that Dr. Sullivan and other leaders in medicine have founded. The purpose of transferring the land is for them to build the National Museum of Health, which will be built privately, operated privately and funded privately.

In the course of discussions with Members of the House and the Senate on this proposal, questions arose with regard to certain issues that are controversial. Among them, the issue of abortion, assisted suicide and things of that nature. After meeting with a number of Members, Dr. Sullivan’s board and those Members

agreed to report language to acknowledge that concern and state the following. The museum will be sensitive in developing mission statements, museum activities and museum content in order to respect the strongly held opinions of a majority of Americans. To that end, the museum should strive to highlight and encourage medical thought history, techniques and technologies that are life-affirming and life-saving. The museum shall develop and report to Congress a viable business plan.

I want to interrupt myself here. The reason for the viable business plan is, there were concerns raised about the Government transferring the land, then building the museum, the museum getting into financial trouble and there being some presumption that by transferring the land there was an implicit commitment to take over the operation and the funding of the museum. So they added the following language.

Should the situation arise whereby the museum is unable to sustain financial solvency, the museum shall not receive funds from the Federal Treasury. So it makes it clear that in transferring the land, which the U.S. Government owns, and the taxpayers, the museum is assuming the financial responsibility, not only for the construction, but for the operation.

So my request of the committee, when the time is appropriate, is that we adopt the land transfer language, which is in Senate Res. 2015, and accompany with it the report language that the Members and the museum board have discussed.

Senator INHOFE. OK, I would say that Senator Jeffords and the minority have agreed to this, so it won't take a UC, and it is now on the agenda.

Senator ISAKSON. Thank you, sir.

Senator INHOFE. Senator Bond.

Senator BOND. Thank you, Mr. Chairman.

I never was one of the Singing Senators, so I would defer to Senator Jeffords, if he wishes to lead us in Happy Birthday to our Chairman. Do you want to try that, Senator?

[Chorus of Happy Birthday to Senator Inhofe.]

Senator BOND. Reclaiming my time before anybody gets hurt—

Senator INHOFE. Up to now, this has been a happy birthday—

[Laughter.]

Senator BOND. You see why the Singing Senators have dissolved.

[Laughter.]

OPENING STATEMENT OF HON. CHRISTOPHER S. BOND, U.S. SENATOR FROM THE STATE OF MISSOURI

Senator BOND. In any event, I thank you, Mr. Chairman, for holding this hearing and wish you well for this and all succeeding coming years. I am delighted we are moving on the authorization for this study today on rebuilding levees. I think people who have fought against levee construction as they did in Missouri after the 100 years floods of 1993 and 1995 will understand why adequate levees are critically important to protect our people as well as property.

I trust, No. 1, that any authorization will come through this committee as the authorizing committee. I think we ought to demand that any projects be authorized, be laid out before us before it goes

to funding. Not that I am against appropriators doing authorizing language, generally, but I think that in this instance we should hold hearings. I think the Corps should look at quite a few options, like filling in the channel which brought the hurricane up to New Orleans. I think they ought to take a look at determining whether there are some parts of New Orleans that cannot be, some of the very low areas, which cannot be effectively and efficiently protected while we protect the very important core of New Orleans. I think we owe that to New Orleans, but we cannot protect the unprotected.

So I trust the Corps will examine those issues and I very much appreciate, as we all do, the great work that Senator Vitter has done, very responsibly bringing forth the need for massive assistance. So I look forward to approving the items on the agenda today and thank you very much for holding this markup and hearing.

Senator INHOFE. Thank you, Senator Bond.
Senator Thune.

**OPENING STATEMENT OF HON. JOHN THUNE, U.S. SENATOR
FROM THE STATE OF SOUTH DAKOTA**

Senator THUNE. Thank you, Mr. Chairman.

I also want to commend our colleague from Louisiana, Senator Vitter, for the extraordinary work that he has done as a very passionate advocate for his constituents in Louisiana, but also for the very thoughtful way that he has gone about this. I think it is important, and we all recognize that when we go about this rebuilding process that it be done in the correct way so that we can avert future disasters like this down the road.

So I appreciate very much his efforts in shedding light on this subject and helping us understand the implications of the decisions that we make and the policies that we put in place. So I want to join and echo what has already been said this morning about the efforts of the Senator from Louisiana with respect to this very, very important issue for him and for our entire Nation.

Thank you, Mr. Chairman.

Senator INHOFE. Thank you, Senator Thune. I have been informed that we do not have any other Democrats coming at this time to attend this meeting, so we won't be able to do even the amendment portion of the business meeting.

So what I would like to ask the Members to do is, let's plan to meet in the President's Room after the first vote and we will have a business meeting at that time, at which time we will take up the amendments that are the manager's amendments as well as the items that require 10 Members.

So with that, I would ask Senator Vitter, if he would come over here and chair this meeting, and we will forego the business meeting until after the first vote.

If you'd like, Senator Vitter, while you are getting prepared, I will tell my birthday story. Would you like to hear that?

Senator VITTER. Mr. Chairman, we'd all love to hear that.

[Laughter.]

Senator INHOFE. November 17 is not only important to me because it is my birthday, not as important to me as it is my 20 kids and grandkids, but it happens that on November 17, 11 years ago

today I also was sworn in as a Member of the Senate. Because it was a special election, I was replacing someone who had retired.

I remember it so well, and this will come as a shocker to those on the left side of this meeting here, I used to be quite a loudmouth, Senator Vitter. I remember the first day I was sworn in, I saw Wendell Ford from Kentucky down on the floor saying something that I disagreed with. I went down and I just really lit into him and it was brutal. I thoroughly enjoyed it.

As I was going back, I went down into the basement to take the train over to the Russell Building and there was Senator Bob Byrd. Now, keep in mind, this was my 60th birthday and the day I was sworn in.

He said, "Young man, I admire your spunk, but we in the Senate do not do it that way like you do," and he went on to tell me about the history of the Senate and it takes unanimous consent and you can't have all that. But I will always remember that as being, my first day here was my 60th birthday, so it is a very special day today. I have mellowed a lot during the years.

[Laughter.]

Senator VITTER [presiding]. Great. Thank you again, Mr. Chairman, for calling this hearing, very important hearing about exactly what caused the levee breaches in the greater New Orleans area immediately following Katrina and what we are doing to solve those problems.

Our first panel is a panel of one, Dan Hitchings, who is the Director of Task Force Hope with the U.S. Army Corps of Engineers. Dan, if you will come up. Dan is going to give us an overview of the Corps work.

If I could ask everyone limit opening statements to 5 minutes, and also, Mr. Hitchings in particular, in addition to giving your testimony and answering questions, I would like to offer you the opportunity to respond, if you would like, after hearing the testimony of the second panel.

STATEMENT OF DANIEL E. HITCHINGS, P.E., REGIONAL BUSINESS DIRECTOR, MISSISSIPPI VALLEY DIVISION, U.S. ARMY CORPS OF ENGINEERS

Mr. HITCHINGS. Thank you.

Mr. Chairman and distinguished Members of the committee, I am Dan Hitchings, Regional Business Director for the Mississippi Valley Division of the U.S. Army Corps of Engineers. I am currently serving also as the director of Task Force Hope, which is our task force that has been put together to respond to the recovery from Hurricanes Katrina and Rita in the Gulf Coast area.

I am honored to be testifying before your committee today on the efforts by the Corps of Engineers to incorporate forensic findings into our ongoing repair of the storm damage reduction projects in the New Orleans area.

With our contractors, we are working around the clock on levees and floodwalls to reduce the risk of damage through the remainder of this hurricane season, which continues until the end of November, and the rainy season that area normally experiences in December and January. Our goal is to complete this phase of the effort before the start of the next hurricane season, which is June 2006.

Our teams are actively gathering data and information from the recent storms, and we have also begun an after-action assessment of the existing storm damage reduction system.

The Corps takes its responsibilities for the safety and well-being of the Nation's citizens very seriously. In the case of the New Orleans area, we are determined to learn what failed, how it failed, why it failed and to recommend ways to reduce risk of failure in the future. There is no single answer to the question as to why there were failures in the storm damage reduction system, as there were multiple breaches of levees and floodwalls at a number of locations, and the failure mechanism or mechanisms are likely to vary. The answer to this will follow from a thorough analysis of the data we are now collecting. The physical process that caused the breaches will be determined from the comprehensive analysis of the data that we are collecting.

What we have to date is evidence of what happened. We can see the final result of the structural behavior, but we cannot yet determine why. That will require more understanding of the design intent of each structure, its condition prior to the storm or the forces to which it was subject, both the static and dynamic, and how we would expect it to respond to those forces. Understanding why this happened will also help us to develop recommendations on ways to reduce the risk of failure in the future.

The Chief of Engineers, Lieutenant General Strock, has commissioned an Interagency Performance Evaluation Task Force to conduct an engineering evaluation. We call this IPET. The IPET includes engineers and scientists from the Engineer Research and Development Center in Vicksburg, the Institute for Water Resources in Alexandria, VA, numerous universities and the private sector, as well as from other Federal agencies, such as the Bureau of Reclamation, and the Oceanic and Atmospheric Administration.

As the team deployed, the American Society of Civil Engineers and the University of California team sponsored by the National Science Foundation approached the Corps about similar studies of infrastructure performance they were undertaking in hopes of applying lessons learned to other levee systems. In the spirit of openness and transparency, we invited them to join our team and beginning on September 29, they joined us for the inspections of the projects involved. On September 30, we learned the State of Louisiana was also going to establish a team of its own, of researchers from LSU and their research center. We also invited them to join the team and they have been participating with us since that time. We are very grateful for their participation.

Over the next 8 months, the IPET will examine and analyze the data and rationally test various hypotheses about the behavior of the infrastructure. Through a thorough analysis of the data we are collecting, we will explore whether human error played any part in the performance of the infrastructure. The IPET will use the collected data, laboratory testing and modeling of activities in its analysis.

The work currently planned includes providing updated and accurate vertical geodetic datum, performance of storm surge and wave modeling, determining the hydrodynamic forces that created the storm, analyzing the floodwall and levee performance when

subjected to these forces, conducting interior drainage and flooding modeling, to include pump station performance and conducting the consequence analysis and a risk and reliability assessment.

We are making all the findings available to the public and invite the public and scientific and engineering community to share any information that they may have. On October 29, we began releasing available data by posting it on a publicly accessible Web site. Additional data will be added to the Web site as it becomes available.

This includes all kinds of information, design and construction drawings, soil sample records, post-Katrina documentation, the hydrographic surveys and soil samples of the data that we have collected in that analysis. It also includes performance data resulting from eyewitness accounts and various photographs of the area.

In addition to the IPET effort, the Secretary of Defense has directed the Secretary of the Army to convene an independent panel of national experts under the direction of the National Academies to evaluate the performance of storm damage reduction systems in New Orleans and the surrounding areas. The National Academies is assembling a multi-disciplinary engineering and atmospheric science team that will be drawn from the public and private sectors and academia.

Until we can collect and analyze all the physical evidence, we will not have a complete picture of what happened. The results of our study will provide a better indication of the extent to which the existing system can be expected to reduce the risk of future storm damage. We will be examining and providing analysis on the performance for the entire storm damage reduction system to understand the failures that occurred, to understand other components of the system that may have degraded in their capacity to protect against future storms and to understand where the system performed successfully.

Nevertheless, I want to emphasize that we cannot wait until the study is complete to begin applying what we have learned. As we learn, we will immediately act to incorporate these findings into the work in which we are now engaged. In the interim, results are being shared on an ongoing basis with the team responsible for the repair of the existing levees and floodwalls. We have established a procedure to ensure efficient transfer of information from designers and the IPET and from the IPET to the designers.

The specific elements include that more than 20 key people from the design team are assigned to work with the IPET. We have established a liaison between IPET team members and specific task force guardian project and technical managers. The Task Force Guardian project and technical managers coordinate all onsite meetings and visits with the IPET members, they conduct joint meetings with the IPET team members when they are onsite, and do trip reports documenting observations and recommendations.

They have a regular weekly meeting to go over things they have accomplished. One of the items on the agenda of this meeting is, what have we learned that would benefit the reconstruction effort currently underway in New Orleans. They will absolutely be talking about this every week and will ensure that we have got that information transferred. The IPET will review all of the construc-

tion plans and specifications and IPET will be involved in the engineering during construction activities.

We will also be producing weekly reports to the Task Force Hope Commander, Brigadier General Crear, on the design improvements and changes made due to this process.

This concludes my statement. Again, I appreciate the opportunity to testify today. I would be pleased to answer any questions that you may have.

Senator VITTER. Thank you, Dan, and we will get to that. I will start it off.

This hearing is about preliminary findings and thoughts regarding why the levees failed. I have to tell you, I find your testimony, even your written testimony pretty frustrating and inadequate, because it does not say anything about that topic. It lays out a process and it doesn't say anything about your preliminary thoughts and findings about what failed and why.

So let's get right down to that meat of the topic. I want to take us through the map of metro New Orleans and move west to east. It seems to me, based on what I read, the following is correct, but please correct me if the Corps disagrees. Let's start to the west, the east bank of Jefferson Parish. There, there were no levee failures and there doesn't seem to be overtopping of the levees. So there, the flooding seemed to be primarily, if not exclusively, the result of rainwater with the pumps not operating, is that correct?

Mr. HITCHINGS. That is correct.

Senator VITTER. OK. Then again, moving west to east, the next area is in Orleans from the 17th Street Canal until you get to the Industrial Canal, not including the Industrial Canal. There you have three interior canals, drainage canals and of course, significant breaches to those. There, there does not seem to have been overtopping of the lake levees and there does not seem to have been overtopping of the canal wall levees. There was some failure from underneath the canal wall levees where they breached. Is that a fair conclusion?

Mr. HITCHINGS. The conclusion of the overtopping is correct. The exact failure mechanism for those floodwall breaches, we still do not know exactly what happened to all those areas, whether if it was a result of scour or some piping underneath, or exactly what the problem was. As you know, we have collected significant data about the existing conditions in those areas. We have done extensive soil borings and subsurface testing that will allow us to conduct that analysis and really determine exactly what failed.

Senator VITTER. So you agree there was no overtopping?

Mr. HITCHINGS. That is correct.

Senator VITTER. So they failed from underneath in some way?

Mr. HITCHINGS. That is correct.

Senator VITTER. Now, some of the outside groups have pointed to porous soil areas, areas of peat underneath which caused the seepage and subsequent failure. What's the Corps' current opinion about that theory?

Mr. HITCHINGS. We concur that those conditions exist. The data shows that. We also concur that that is a possible contributor to the failure. However, we do not know if that is the only contributor or if it was the sole cause in those particular cases.

Senator VITTER. What would other possibilities be? You mentioned some piping areas.

Mr. HITCHINGS. There is some evidence of trees that had grown up onto the edge of the embankment of the levees. There is a theory, that of course is being examined, about whether or not the growth of those trees and perhaps subsequent failure of those trees during the wind storm that was generated as part of the storm may have contributed to those areas.

So it may not just be the subsurface conditions in those particular areas. It may also be other conditions. There is data that Louisiana State University has that suggests that the sheet piling is at a depth of minus 10 feet. That suggests that that also may have contributed to the failure.

Senator VITTER. Have you confirmed that?

Mr. HITCHINGS. We have not yet confirmed that. We have done testing to actually examine those areas, using a subsurface probe that uses an echo type mechanism to do that. We do have some data from that, but we have to validate that data to determine exactly where those holes were, so we can try to confirm with LSU if we are talking about the same location.

Senator VITTER. Does the data point to the 10 feet being correct or incorrect so far?

Mr. HITCHINGS. The locations that were tested indicate that the sheet piling depth was around 10 feet. What isn't confirmed is whether or not this is in locations where the depth of the sheet piling should be more than 10 feet.

Senator VITTER. My understanding was the whole design was sheet piling depth to 17 feet. There was no area where the design was only 10 feet, was there?

Mr. HITCHINGS. I do not know that to be true, that it was all required to be at 17 feet. That is what we are trying to confirm today, sir.

Senator VITTER. OK. Obviously that is very serious, because the allegation is even the design, which was probably inadequate, even the design was to 17 feet, and yet you go back and look at it, and it went down to 10 feet, just to clarify for everyone.

Mr. HITCHINGS. We agree that those conditions are serious.

Senator VITTER. Again, moving from west to east, the Industrial Canal, seems there you had storm surge built up in part by Mississippi River Gulf Outlet leading into the Industrial Canal, channeling that storm surge, building it up even higher, significant overtopping of the levees there, and then failure at some points there. Is that an accurate summary?

Mr. HITCHINGS. Yes. The floodwalls and levees in that Industrial Canal area were overtopped. The evidence shows significant areas of scour on the back sides of those floodwalls in particular, and it shows evidence that the water was flowing over the top of them before they failed.

Senator VITTER. So you would say the best theory now is that significant overtopping, scouring out of earth on the land side of the wall and then the wall gave way?

Mr. HITCHINGS. That appears to be a likely scenario.

Senator VITTER. Then again, continuing to move to the east, in eastern New Orleans and St. Bernard Parish, which is closer to the

storm and the Gulf, seemed to have had major overtopping in many, many places, which led to many breaches. Is that fair to say?

Mr. HITCHINGS. That is correct. This map shows the Orleans East area. You can see that the majority of the breaches perhaps point out on the southeastern corner where the red spots are is where the breaches would mostly occur. The area that borders on the lake, Lake Pontchartrain, however, did suffer one area that was damaged. But most of that was not breached. It was overtopped but was not breached.

Senator VITTER. OK, my time is well past due, so I will turn it over to Senator Isakson.

Senator ISAKSON. I do not know New Orleans as well as Senator Vitter, so I can't follow directions as well. But it appears to me that the overtopping occurred mostly on the east and south and that the north breaches were somewhere down in the levee, is that correct?

Mr. HITCHINGS. The breaches, to go back to that first particular chart, the overall area, most of the breaches occurred in the area that, if you would point to this area above St. Bernard along the levee that was adjacent to the Mississippi River Gulf Outlet and then also on the portion of New Orleans East. It is important to note also that the levees along the Mississippi River that protected the portions of Plaquemines Parish were all significantly overtopped in that area.

Senator ISAKSON. That is kind of what I observed. It leads me to this question. Before Katrina, upon our election, I was with some people from New Orleans who talked about the tremendous erosion and loss of land in the barrier islands and the wetlands south of New Orleans. I know we are talking about the reconstruction of the levees and the reasons why there were failures.

But I am becoming, and I am not an engineer by any stretch, did some land development. But should we not, in tandem with looking at the reasons for failure of the levee per se, also look at what we need to do on these wetlands and barrier island areas and other areas? Because the lessening of their ability to take some power out of these storms is going to put increased pressure on the levees. So it seems like it is a tandem deal. Am I wrong?

Mr. HITCHINGS. No, I would agree with you. In fact, the analysis that is being conducted on the storm surge is going to be looking at the conditions that existed when the projects were designed, and also the conditions that exist now. The storms produced a significant loss to the wetlands and barrier islands that do in fact provide some storm surge reduction. So we are going to be looking to see what the impact is.

Obviously that has an impact into the future, and as we look at risk and reliability of the existing system, after we get it reconstructed to its pre-storm design level, we need to know what level of protection that is under the existing conditions.

Senator ISAKSON. Two other quick questions. One, can you really go ahead and do the restoration without having the game plan for the wetlands? Or should you? You could, but should you, I guess.

Mr. HITCHINGS. I think the important thing that we are working on right now is an extremely urgent matter, to get the portions of the project that were damaged restored before the next hurricane

season. That is absolutely the top priority to ensure that protection, at least to that level, is available.

Senator ISAKSON. At least to Category 3?

Mr. HITCHINGS. Well, it is to the design level. I know some testimony earlier before this committee explained to some degree, when the project was designed, the hurricane scale did not exist. So it was designed to a standard project hurricane, elements of which fall within Category 3.

Senator ISAKSON. I appreciate your making that observation.

Mr. HITCHINGS. People would suggest, a Category 3 storm, I believe, goes up to winds up to 145 miles an hour. These protection facilities were only designed for winds of around 100 miles an hour.

Senator ISAKSON. The levees have been temporarily repaired, or have those huge sand bags holding back part of the water, is that correct?

Mr. HITCHINGS. Right now, that is correct.

Senator ISAKSON. Out of curiosity, and I have thought about this a few times, how you repair a levee and hold the water back at the same time, is it going to mean that the existing repaired levee walls and berms stay in place and you actually move the levees slightly, the new construction is off that?

Mr. HITCHINGS. Each particular breach has its own answer to that, and they are being looked at. I can show you an example of one that we are working on, the floodwalls at the 17th Street and the London Avenue Canals. If you would just show that one section with the setback. There is another drawing in there.

[Slide shown.]

Mr. HITCHINGS. What that shows basically is the canal running across the page there. That black shaded area is basically the area where the temporary berm has been constructed. The heavy black line outlined with yellow shows that we are going to be constructing a sheet pile wall to protect that. So the first thing we did is plug the hole, basically, we put sand bags and gravel and stone in that area to stop the water from going back and forth. Then we reinforced that so it would be a little bit stronger.

The next thing we are currently doing is putting the sheet pile along that area. That will now allow us to remove that old plug, and then rebuild that section to the correct design in there. Each particular breach, depending on its physical characteristics, has something like that. Some of them will in fact have a setback levee, other ones will be done like this, and in some of the areas, we actually can construct them in the clear, because there is another line of protection available.

Senator ISAKSON. I know my time is up, but sheet pile, is that the temporary metal?

Mr. HITCHINGS. Yes. It is long sheets that interlock on their edges and go down side by side.

Senator ISAKSON. Thank you, Mr. Chairman.

Senator VITTER. Thank you, Senator.

I want to go back to the map and again move west to east and talk about the work going on between now and next June and exactly what that is. We will start with the 17th Street Canal. As I understand it, you are driving sheet piling down to a significantly

deeper depth than the original design, and that is to what, 40-plus feet?

Mr. HITCHINGS. I believe that the sheet pile length is somewhere between minus 60.

Senator VITTER. Sixty, OK. For what span of the canal are you doing that?

Mr. HITCHINGS. Currently, we are doing it for the areas where the breaches are. That is part of the temporary closure. There is a couple reasons for that. One of the most significant is, as you know, when that levee area and floodwall breached, there was a significant amount of scouring, not only in the area of the breach, but also scouring from the bottom of the canal itself, with the volume of the water that was flowing through there. So the subsurface conditions have changed, so we need to make sure the tips of those sheet piles are deeper.

Senator VITTER. In that area where it breached, what was the depth of the sheet pile?

Mr. HITCHINGS. It is my understanding that the intent, the design depth was minus 17.

Senator VITTER. What was it?

Mr. HITCHINGS. I do not know that. We have not got that data. As you can imagine, that sheet piling is now buried under that temporary closure. So as we build that new sheet pile closure wall, we will be taking the earth and sand bags all back out of there and actually have those sheet piles that were in that area available as physical evidence.

Senator VITTER. Will you do this reconstruction with a far deeper sheet pile in all other parts of the canal?

Mr. HITCHINGS. I do not have the exact answer for that. What we are doing, we are examining the entire lengths of those canals. As you can imagine, that is what would be prudent.

There are a number of other areas that didn't breach, but that did receive some damage. So we are collecting all of that data about the condition of those sheet piles and looking at the design parameters. We have done an extensive amount of subsurface examination, collecting additional data on what the conditions are, and what the soils actually are in that area.

So we will have a design in that area that is appropriate to provide the protection. It is possible that that design may indicate that the entire lengths of those sheetpiles are not adequate. I do not know the answer to that. But that is within the range of possibilities.

Senator VITTER. Let me ask it another way. If this section failed, what would cause you to believe that all sections would not have to be redesigned and improved?

Mr. HITCHINGS. Well, trying to determine exactly what the cause of failure was. If it was a tree, for example, that was on the back side of that levee, and the tree fell over, which created a hole in the back side, and that allowed the water to percolate through, that would be a condition that probably wasn't relevant to the design. It was a change to a condition afterward.

Senator VITTER. Right, but Dan, as far as I know, nobody thinks that is the leading theory for the cause. Everyone thinks, as far as I know, that the leading theory for the cause is the sheet piling not

even going to the depth of the canal, No. 1, and there being weak soil layers, No. 2, that contributed to the seepage underneath.

Mr. HITCHINGS. If that is what we conclude, then we will ensure that the design that is used for the future is adequate to meet the design levels of that.

Senator VITTER. What's the timeframe for reaching that conclusion? Because obviously, we are trying to reassure folks that by next hurricane season this will be fixed. But if it is fixed just for the area where there was a breach, that is not terribly reassuring.

Mr. HITCHINGS. That's exactly correct. If the conclusion is that that entire system needs to be reconstructed, it will not be possible to do that by June 1. We are working on a concurrent plan to put a more permanent temporary closure at the mouth of the canals, at the lakefront. What that would do is provide us the ability, when a surge occurs, to close the lake off so those sections of floodwalls would not be subjected to the surge.

We would also have to put in a temporary pumping system that would allow the interior drainage pumps to pump so that we didn't worsen that condition. So because we do not know the exact answer, and believe me, the engineers are working as quickly as they possibly can to get the answer on the design adequacy of that floodwall system. We know that there isn't sufficient time, so we are working on that plan for temporary closure concurrently.

Senator VITTER. So again, going back to the primary question, when do you think you are going to know whether the areas that didn't happen to fail in this storm event are designed and built adequately or not?

Mr. HITCHINGS. It will be within the next 30 days.

Senator VITTER. The next 30 days?

Mr. HITCHINGS. Yes, sir.

Senator VITTER. So presumably that will include some analysis of where these weak peat layers are.

Mr. HITCHINGS. Yes. Based on the data that we have collected, we will know and be able to make some assumptions. As you can imagine, in this particular area where much of it was previously a swampy area, the subsurface conditions vary significantly. So we can't poke a hole everywhere, but we have poked a significant number of holes that will give us a better picture of what those conditions are.

Senator VITTER. Is it the Corps' preliminary conclusion that the peat layer, if that exists, that is pretty general or localized?

Mr. HITCHINGS. I do not know the answer to that.

Senator VITTER. Do you know how frequently you are boring soil samples to test things like that?

Mr. HITCHINGS. I do not have the actual interval.

Senator VITTER. I mean in terms of distance.

Mr. HITCHINGS. I know how many of them that we have put in.

Senator VITTER. I have been told you have done about 60 so far, and your standard is 300 meters.

Mr. HITCHINGS. Yes, sir, that is correct. We have done a total of 60 Cohen penetrometer tests, with an additional 20 borings.

Senator VITTER. Three hundred meters strikes me as a pretty significant distance not to test between. What's your reaction to that?

Mr. HITCHINGS. Well, no, that is the normal design that you would do. I mean, engineers are allowed to put it at closer intervals if there is a reason to believe that they needed that additional data.

Senator VITTER. OK. Senator Carper.

Senator CARPER. Good morning, Senator Vitter.

Senator VITTER. Good morning.

Senator CARPER. How are you?

Senator VITTER. Good.

Senator CARPER. You looked kind of lonely in here, I thought I would come in and join you.

[Laughter.]

Senator CARPER. I want to welcome our witness, Mr. Hitchings.

Mr. HITCHINGS. Thank you.

Senator CARPER. Thank you for joining us today. I missed your testimony.

Let me just ask you first of all, just take a minute and what should be my takeaways from what you have had to say. If you can just crystallize it in a minute or two, then I have a couple of questions I am going to ask you.

Mr. HITCHINGS. OK. We have been immediately responding to the storm. That required us to do some temporary measures, and then also to do some things as rapidly as we could so we can restore protection by June of next year before the hurricane season.

Concurrently with that, we started a data collection effort that is leading to an analysis of what happened, why it happened, and what that means to the integrity of that storm protection system. Those two things are on parallel paths.

However, the design and repair of the structures can't wait until we get all the answers. That is the problem that we face. It is a situation where if we wait until we have the answers, we will never get it done in time.

So we have put a mechanism in place to transfer information between the team that is doing the investigation and collecting the data and doing the analysis and the teams that are doing the redesign and construction of this, so that that information can pass back and forth, basically on a zero time basis, that they are moving, as soon as somebody knows something here, we are passing it to the design team. As soon as the design team encounters something, we are passing it to the investigative team to know that.

I mean, that's essentially what the essence of my statement is.

Senator CARPER. Thank you. At a recent hearing of another committee I serve on, Homeland Security and Government Affairs, there was a fellow named Seed, Dr. Seed, do you know him? S-E-E-D.

Mr. HITCHINGS. I do know him, yes.

Senator CARPER. He was a witness who was representing, I think, the National Science Foundation, their investigation team. But anyway, he testified that there are some fairly simple, fairly inexpensive floodwall improvements that could have, in their view, prevented if not all then some of the breaches that occurred. I do not know if you have any knowledge of what he might be alluding to, and let me just ask, is it possible for the Corps to incorporate

some of those less expensive modifications into the repairs to the floodwalls that are currently underway?

Mr. HITCHINGS. Absolutely, and we have done that.

I have a chart here that lists some of the things that are there. This is, probably for an engineer, this is easy to look at. But for the designers, this is what it is, in the dashed line on the front side of this——

Senator CARPER. Let me just ask the gentleman who is helping you, if he would maybe serve as a pointer and just point out what you are referring to, that would be helpful.

Mr. HITCHINGS. Point to the eyewall construction on that if you would, Zoltan.

[Slide shown.]

Mr. HITCHINGS. Start with that, the eyewall and the dash line to the left. That is what the existing design was. The suggestions, one of the suggestions that was made from the investigative team suggested we have a different type of wall there, a T wall. That T is what is shown in the darker lines. You can see that that is a significantly stronger design. That is what's being used in the area of the Industrial Canal.

Also on the landward side of that, they are putting scour protection in. Because these floodwalls in fact didn't fail from the water pushing against them, they failed because they were scoured on the back side and then collapsed. So we are putting scour protection on the back side of that.

[Slide shown.]

Mr. HITCHINGS. The next chart that is just a word chart there lists a number of other things that we have incorporated in the design already, results of the input that we have received from not only Dr. Seed, Dr. Bee, Peter Nicholson, who is part of the ASCE team and other Corps of Engineers and other LSU team members who have been part of this. As they identify things, we are incorporating them into the design.

I would suggest that it really doesn't matter how late it is that they identify that. If it is a critical item that will require strengthening or a different design of part of the structure, even if it is in June of next year, we will go back and make that correction.

Senator CARPER. Good. Thanks. Our thanks to your assistant here as well.

A second question, if I could, I understand they have these levee boards, and I am not sure how they are structured. But in your opinion, how does this levee board structure exist, with separate board, I guess for each parish, how does that impact the ability of the region to develop a comprehensive flood control system for the metropolitan area, greater metropolitan area? Does it improve or does it worsen the oversight of spending?

Mr. HITCHINGS. I am not sure that it worsens it. It obviously makes coordination a little bit more extensive when you have to work with different groups. It also makes some of the decision-making a little bit difficult, if they have different opinions. We work also with the State of Louisiana. Their State Department of Transportation and Development has responsibility for the flood control measures. Normally, when a particular project spans multiple jurisdictions, they have the opportunity to come in and be the

local sponsors. They then sign, and they work the coordination with the individual levee boards as part of it.

But we have worked with these levee boards for decades. None of them are new. We have had relationships that go back a very long way. So yes, it does complicate it, but it doesn't create a situation that is untenable.

Senator CARPER. My time is expired. Mr. Chairman, could I ask one more, kind of a follow-up to this levee board structure question?

One of the weaknesses identified in the current levee system involves transitions in floodwalls from one type of material to another, from concrete to sheet pile between the different heights of floodwalls and levees. How can the coordination between the various levee boards be improved to address those perceived weaknesses?

Mr. HITCHINGS. One of the things obviously is to make sure that as we go through the design process that we are more cognizant of the impact of those transitions. I am not positive that it is always a levee board issue as much as it is two other things. One is, different parts of the structure require different solutions, particularly where there is a crossing. If you would have a crossing for either road or railroad or pipeline, you normally may not put that through a levee section, you would put a floodwall there, something that you can put stop logs in to prevent the water from going through. But you normally would leave it open.

That requires a concrete structure for those stop logs to connect to. In the transition is where that concrete then goes back to a levee section. So the awareness that we now have is that we need to make that transition smoother. We need to, in fact, embed that concrete deeper into that levee, rather than have a shorter overlap of those. Also make sure that we construct them to the same level.

Another complicating factor, of course, in this area, is the settlement that occurs in these areas floodwalls and levee sections will settle at different rates, just because of the weight that is associated with them. So that settlement will result in a section of levee that perhaps ends up being lower than the top of the floodwall, which then creates a situation where the erosion may be higher and result in a breach in those areas.

So all of those require us to be more sensitive to those issues as we go through this redesign process.

Senator CARPER. Mr. Hitchings, we appreciate your being here today. Thank you for your testimony and for responding to my questions.

I have two other hearings that are going on simultaneously in two other of my committees, so I am going to slip out. I regret I can't stay longer. If I can get back here, Mr. Chairman, before you are done, I will be back.

Senator VITTER. All right, thank you for being here.

Dan, to go back to our conversation first about the 17th Street, I believe what you said is within a month, the Corps will determine if conditions elsewhere along that canal where it did not breach or substantially similar to conditions where it did breach. If the answer is yes, they would reconstruct those other lengths of the canal wall as well.

Mr. HITCHINGS. That is one option. There are several options that we are looking at as opposed to just reconstructing what was there in a stronger way. One of them might be to eliminate the floodwalls portion of it and just reconstruct levees.

The consequence of that is it requires a much larger footprint that affects the real estate that is there, property owners that are there. There is a plus because the levees appear to be a more desirable solution than the floodwalls, but the consequence is taking property.

Another option that could be considered would be that permanent closure at the end of the lakefront area there, where we have gates in place. Instead of just doing it with temporary structures, do it with a permanent gate operation.

Another option to be considered is whether or not we just want to put pumps, pumping stations at the lakefront to supplement those, totally close that system off so that it does not drain naturally into the lake, but install pumps into it. Of course, all of those have cost consequences. We would have to coordinate that with the local sponsor to get their input into that process, and then also work to get the additional funding for those.

Senator VITTER. The Corps will come to that conclusion about whether one of those options is necessary within the next month?

Mr. HITCHINGS. Yes, sir.

Senator VITTER. If the answer is yes, why wouldn't the Corps, the Corps has authority, because it is acting on it right now, rebuilding that section to a better design now at 100 percent Federal cost, why wouldn't that be true for the whole length of the canal that needs to be designed and constructed better?

Mr. HITCHINGS. Well, as soon as we determine what the design needs to be, we will do that, absolutely.

Senator VITTER. And you will follow this precedent, which is that you have the authority to do it now, no more authorization, and it is 100 percent Federal cost?

Mr. HITCHINGS. Yes. The only question though that our lawyers are looking at at this point in time is whether or not putting those pump stations out at the lakefront would be considered within the scope of the authority that we have.

Senator VITTER. But everything else, you would think, is within the scope of your authority?

Mr. HITCHINGS. Certainly rebuilding the parallel protection system as it was described and authorized is within the scope of our authority, yes.

Senator VITTER. Now, going to the Industrial Canal, same sort of question. You have a fundamentally different design, an inverted T.

Mr. HITCHINGS. Right.

Senator VITTER. Are you doing that beyond the area of the breach?

Mr. HITCHINGS. No, not at the this time.

Senator VITTER. OK. What if anything are you doing beyond the area that breached?

Mr. HITCHINGS. Well, beyond the area of the breach we will be putting the scour protection in, on the back side of those. Again, the hypothesis being that those walls didn't fail until after they

were overtopped and scouring caused those failures. Providing scour protection behind the existing eyewalls would be an improvement that would prevent them from failing. So because they were all scoured, we have to go in there and make those repairs anyway, we are going to be doing it with materials such that the scouring won't occur if it was overtopped again.

Senator VITTER. Obvious question, if you think this new design with an inverted T is necessary where the breach happened to occur this time, how do we explain to residents that we are not doing it everywhere else?

Mr. HITCHINGS. Well, there is no indication at this point that the eyewall was in fact inadequate design. It failed, the failures occurred because of the scouring. If we can prevent the scouring, then the eyewall would be adequate.

Senator VITTER. Well, let me ask another obvious question. If that is true, why are you using the inverted T where it breached? Why do not you just go back to the original design, if it is so great?

Mr. HITCHINGS. I understand your line of questioning, and it is appropriate. The T wall is a stronger wall section. So that is why it is being used in this particular place. As long as we have an opportunity to reconstruct it.

Senator VITTER. Let me just, I guess it is clear, but let me just express the concern that we are using a better design, but only for the area that happened to breach this time. There is no evidence that the circumstances that led to that breach do not exist all up and down the canal on both sides. So that is an obvious concern all of us have in the community.

Again, continuing to move east, what is the Corps doing in the short term now, to June, et cetera, with regard to the New Orleans East and St. Bernard levee systems that had pretty massive overtopping and failures?

Mr. HITCHINGS. In each of those areas, the breaches are being repaired. Some additional scour protection is being put in in some of those areas where there is evidence that there was damage and erosion at the toes of those sections. So we are putting in some of the scour protection. But the sections that were damaged themselves will all be repaired back to their original design level.

Senator VITTER. In those areas, as well as other areas, will the rebuild take account of subsidence that is occurred since the design and construction?

Mr. HITCHINGS. Yes. We are rebuilding, it gets extremely confusing to everyone when we talk about levels, because we talk about design level, we talk about authorized level, we talk about 17 feet. It tends to be different in each area.

To try to keep the confusion to a minimum, what we are referring to is to the original design level for those indications, which was what it was constructed to or authorized to be constructed to when it was originally built. So that would take into account previous subsidence.

We also tend to build those with a few feet extra on top of them, because you know subsidence is going to continue. You do not want to have something that 1 year after you finish it is no longer at the design grade.

Senator VITTER. Will that be done throughout the metro area in terms of the levee systems?

Mr. HITCHINGS. Right now, the emphasis for the June 1 effort is to do that for the areas that have been damaged, not for the entire system.

Senator VITTER. What about beyond June 1?

Mr. HITCHINGS. For the Chief, we are now putting together a total requirement. We are making an assessment of the entire system from one end to the other and identifying what the scope and cost of all those improvements would be. As you know, we focused our attention on those areas that were damaged, so we could get those breaches fixed as quickly as possible. So now the next step is that assessment and identifying what the requirements are to get the whole system up to its authorized level.

I will point out as well that that authorized level also includes a re-analysis of the storm surge.

Senator VITTER. OK. Well, again, to state a general concern, of course we need to fix the breaches first. But to improve the design only at the breached areas and stop there makes no sense, because the same factors seem to obtain everywhere else along the system. Now, I understand you can't do everything at once and you can't do everything between now and June. But it is important to do that all eventually. So will the Corps do that same work all along the system, even though it may take beyond June in other areas beyond where the breach occurred?

Mr. HITCHINGS. We will in fact look at whether or not that kind of work is required. It is really the concluding segment of the IPET's work, is the risk and reliability analysis. What we expect as a product from that is a recommendation that communicates to us which we can work with the locals and with Congress on what needs to be done for that entire system.

The expectation obviously is if it is a lot of money, then as you know, the project was not finished being constructed. There were still sections of it that needed its initial work, as well as funding required to go back and raise those sections that had had their first lift on them. So there is going to be a substantial funding requirement associated with that.

So we will identify that requirement and communicate it, if it is within our authority, then I am sure that we will request the funding to get that moving.

Senator VITTER. Final question. You know many of the outside groups have made the conclusion that there is a particular weakness and vulnerability at transition points where designs change.

Mr. HITCHINGS. Yes, sir.

Senator VITTER. Part of my concern is in that in fact with this immediate work, you are increasing the number of transition points. How do you address that?

Mr. HITCHINGS. The intent there is to be aware of the vulnerability that exists at those transition points and to mitigate that vulnerability to the maximum extent possible. One way is to make sure there is a more smooth transition between heights of existing sections. So if there is an existing floodwall that didn't damage but there is a levee right adjacent to it, let's make sure that we bring that levee up to the same height.

Let's also ensure that the floodwall is embedded deeper so that if there is some type of erosion around that soil at the transition, that there will be floodwall underneath to strengthen that area.

Senator VITTER. OK, thank you very much, Dan. I want to repeat, we very much want you to stick around and listen to the further testimony and then we will give you a chance to come back and make any points in response to that.

Mr. HITCHINGS. Thank you.

Senator VITTER. Thank you.

Dan, if we could ask, if you could submit the Corps' list of design revisions for the record, that is an important point of information.

Mr. HITCHINGS. Yes, sir.

Senator VITTER. Thank you.

Now we will invite up our second panel. As they come up, I will introduce them. A very distinguished panel, Mr. Thomas F. Zimmie, Ph.D., professor and acting chairperson of the Department of Civil and Environmental Engineering at Rensselaer Polytechnic Institute, and a key member of the National Science Foundation Investigative Team; Mr. Sherwood Gagliano, Ph.D., president of Coastal Environments, Inc.; Mr. Larry Roth, deputy executive director of the American Society of Civil Engineers; Mr. Joseph Suhayda, Ph.D., emeritus engineering professor with LSU; and Mr. Robert Verchick, professor at Loyola University Law School in New Orleans.

Thank you all very much for being here, and I would invite you all to give opening statements of 5 minutes duration. Of course, you can submit anything in addition for the record if you so wish.

Dr. Zimmie.

**STATEMENT OF THOMAS F. ZIMMIE, Ph.D., PROFESSOR AND
ACTING CHAIR OF CIVIL AND ENVIRONMENTAL ENGINEERING
DEPARTMENT, RENSSELAER POLYTECHNIC INSTITUTE**

Mr. ZIMMIE. Thank you. It is certainly an honor and a pleasure to be here. I thank Senator Vitter and the rest of the Members from the committee, the rest of the Senators, although you seem to be it at the moment.

My comments will be kind of informal and they more or less echo the statement I put in. You have already introduced me so you know I am a professor of civil engineering at RPI up in Troy, NY. I was a member of the National Science Foundation sponsored investigative team. Of course, our boss was Ray Seed, the professor at Berkeley whose name came up. So my comments echo a lot of the team members' comments.

We produced the report, which I am sure you have, you saw that preliminary report on the performance of the New Orleans levee system. Of course, there was not just the National Science Foundation sponsored team, but it was also an ASCE sponsored team and other team members. So there was a wide range of experience.

I should say that any opinions I express here today are mine alone and do not necessarily reflect the views of the National Science Foundation or any other group or other agency. I do not have any financial interest in a consulting firm that is going to get contracts to repair the levees, etc. Our efforts were volunteer efforts, considered to be a professional contribution.

I spent about a week down there in about the middle of October, although our teams were there from the end of September, a good part of October. We were there in about four different teams. Of course, we looked at all the major breaches and probably saw several dozen breaches down there.

There is not one simple answer as to why the levees failed. I think that is been covered pretty well by the previous witness. We have various causes: overtopping, erosion, failure in foundation soils, seepage, underlying, and that is not even a complete list. The idea of our investigation, of course, was to try to come up with some preliminary observations, and they were preliminary, the report says preliminary, that is the first word. We hope it will lead to better designs in the future, that is the idea. Of course, we hope that the lessons learned from this event will lead to improved protection in the future, not just in New Orleans, but throughout the Nation and around the world.

The emphasis today is New Orleans, but we really have thousands of miles of levees in the United States, and I mean thousands, not hundreds, thousands. We have hundreds right in New Orleans, over 300 miles. Every State has some levees.

That is about all I have to say. I am basically here to answer questions and hope I can be of assistance.

Senator VITTER. Thank you very much.

Dr. Gagliano.

**STATEMENT OF SHERWOOD GAGLIANO, Ph.D., PRESIDENT,
COASTAL ENVIRONMENTS, INC.**

Mr. GAGLIANO. Thank you, Senator Vitter. It is indeed a pleasure and an honor to give testimony to this distinguished committee. I want to particularly thank you for allowing me to discuss a rather controversial and difficult topic. It is controversial because it involves and challenges some of our long-term concepts and theories about geology and engineering design and other aspects of levee building and coastal restoration. It is relevant to how we rebuild coastal Louisiana.

I have been a geologist and have spent my professional career working in the Mississippi River deltaic plain of Louisiana on erosion and restoration problems. Particularly in the last 5 years, I have focused on the effects of geological fault movement on land subsidence and erosion. Underlying south Louisiana is amaze of deep-seated, geological faults that are experiencing accelerated movement during recent decades. This movement is affecting surface land forms and features.

I have given you two handouts. In these handouts, I have tried to demonstrate two things. No. 1, the nature of the fault movements, and No. 2, the effects that the fault movement had on levee breaches that occurred during Hurricane Katrina in south Louisiana. The handout entitled "Effects of Earthquakes, Fault Movement and Subsidence on the South Louisiana Landscape" was published in February 2005, and deals with the topic that is before us now.

I have evaluated a number of the Hurricane Katrina levee and floodwall breach sites, not all of them and not all of them in great detail. I have found evidence that confirms the concept that these

faults that extend deep into the subsurface of the earth have been active in modern decades and may have contributed to some of the breaches. Some of the failures were clearly overtopping, because the levees were simply not high enough to stop the surge. But there is evidence that the breaches on the 17th Street Canal, the London Avenue Canal, and the Inner Harbor Navigation Canal occurred at locales where the levees were constructed across geological faults and that poor foundation conditions associated with the fault planes contributed to the levee and floodwall failures.

I have great concern that proposed and existing levee alignments throughout south Louisiana cross many geological faults that are known to be active. This has not been taken into consideration in levee alignment and design simply because the fault hazard was not previously recognized. This is relatively new theory, new information, and new science.

I have greater concern that there has been resistance to evaluation of the fault hazards. The resistance is a denial process. We have uncovered the root cause of the disease that is eating away coastal Louisiana lowlands. The effects of 50 years of accelerated fault movement that has caused massive land subsidence and weakening of hurricane levees was made apparent by Hurricanes Katrina and Rita. The fault cracks that extend thousands of feet below the earth's surface are actually affecting the works of man on the surface. Fault movement is a natural hazard that has been seriously underrated and not addressed. I hope that this committee will help bring it to the attention of engineering and planning community as we repair the levees and prepare Louisiana for the future.

The fault hazard notwithstanding, I strongly believe that we can provide adequate storm protection around the perimeter of the greater New Orleans area and for much of south Louisiana. We possess the science and technology to design and construct a sustainable flood protection system area that will protect the area where the people who manage and harvest many important resources for this Nation work and live. I also believe that we can wrap a sustainable natural systems management program around the protected areas of the Louisiana coast.

We are all here to try and do that in the best possible way. My testimony is not intended to be criticism of past decisions. It is intended to be constructive input into the rebuilding process. Thank you.

Senator VITTER. Thank you very much, Doctor.
Now Mr. Roth.

**STATEMENT OF LARRY ROTH, P.E., DEPUTY EXECUTIVE
DIRECTOR, AMERICAN SOCIETY OF CIVIL ENGINEERS**

Mr. ROTH. Thank you, Senator Vitter.

Good morning. My name is Larry Roth. I am the deputy executive director of the American Society of Civil Engineers. I am very pleased to appear before you today to testify on behalf of ASCE to discuss preliminary findings on the failure of Gulf Coast levees during Hurricane Katrina, and also to the degree to which levee repairs are incorporating these findings.

I am accompanied today by John Headland, P.E., principal engineer with Moffatt and Nichol Engineers, and a member of the ASCE Levee Assessment Team in New Orleans.

I am a licensed professional engineer and a licensed geotechnical engineer in the State of California. Before joining ASCE staff, I had 30 years experience in water resources and geotechnical engineering working on issues such as dams, levees and canals. Following Katrina, ASCE assembled several teams of experts to examine failures of the New Orleans levees as well as to examine shoreline damage along the Alabama and Mississippi coastline.

Our New Orleans team was joined by another team from the University of California at Berkeley. These teams were in turn joined by employees of the U.S. Army Corps of Engineers' Engineers Research and Development Center, which provided considerable insight and logistical support. The purpose of this joint site visit was to gather information about the failure of the levees, including data that would be lost during the process of levee repair and the passage of time.

In the meantime, Defense Secretary Donald Rumsfeld announced in October the creation of an independent panel of national experts under the direction of the National Academies of Science to evaluate the performance of the hurricane protection systems in New Orleans and surrounding areas. This panel will perform a high level review and issue a final set of findings based primarily on the data gathered by the Interagency Performance Evaluation Task Force, or IPET. The IPET will include a broad interagency participation, the private sector, and academic expertise. The IPET is to obtain facts by collecting, analyzing, testing and modeling data and information on the performance of the New Orleans hurricane protection system during Hurricane Katrina.

Secretary Rumsfeld also authorized ASCE to convene an external review panel to conduct continuing expert peer review on the work of the IPET. The ASCE external review panel, of which I am chief of staff, will also report findings to the National Research Council. On November 7 and 8 of last week, the external review panel met in New Orleans with the IPET and was able to conduct its first on-site investigations of the levee system from the air and on the ground.

Earlier in November, the ASCE and University of California Berkeley teams released a joint report entitled, "Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina" on August 29, 2005. As the title clearly indicates, this is a preliminary report. Final conclusions on the failure of the New Orleans levee systems must await the study being conducted by the Corps' IPET, which is scheduled for release June 1, 2006.

Hurricane Katrina was a catastrophic storm that made landfall in the Gulf Coast near the Louisiana-Mississippi border with wind speeds near 150 miles per hour. But the damage in New Orleans due to high winds and rain paled in comparison to the devastation resulting from the flooding. Where the storm surge was most severe, this cause massive overtopping and the levees experienced a wide range of damage from complete obliteration to those being intact with no signs of distress. At some locations, the earth embank-

ments were simply gone. Some walls with embedded sheet piles fared only marginally better and were often breached as well, even though they were not always overtopped.

Another commonly observed problem was the frequent presence of transitions between different sections of the levees, which include inconsistent crest heights, changes in levee type, changes in materials of construction and rights of way penetration through the flood control system. As you know, the Corps of Engineers began making emergency repairs to the levee system in the immediate aftermath of the hurricane. These repairs were necessary to complete the evacuation of the city, to aid in the removal of the floodwater and to restore order. The Corps has now begun making longer term repairs. Construction crews are installing temporary coffer dams around the breached areas to keep water out while permanent repairs are made. The initial temporary repairs are being removed.

The Corps will then install new sheet piles, presumably to greater depths, and T walls to provide greater lateral support and better protection against seepage. In addition, the Corps will need to inspect distressed floodwalls to determine whether to repair or to replace them. The Corps will also need to inspect apparently undamaged floodwalls and levees to determine if they have hidden structural damage or weaknesses.

Based on our observations, a number of initial comments are warranted concerning the rebuilding and rehabilitation of the levee systems. While levee failures may be expected when overtopping occurs, the performance of many of the levees and floodwalls may be significantly improved and the likelihood of future failures prevented with relatively simple modifications of the levee and floodwall system.

For example, the levees need additional overtopping protection on their inboard sides to minimize erosion. The crest heights of the levees need to be planned in a systematic and deliberate way so that if and when overtopping does occur, it occurs preferentially at desired locations where the walls are more robust or designed to better resist overtopping.

Transitions should also be improved so they do not represent locations of potential weakness. The storm surge that was funneled through the Mississippi River Gulf Outlet was a significant factor in the overtopping of the levee system. The Port of New Orleans and the Corps must carefully consider whether the danger posed to human life and property by future storm surges down the outlet warrants keeping the channel open.

We believe Congress should enact a national levee inspection and safety inspection program modeled on the very successful Dam Safety Program. The levee program should include a national inventory of levees, particularly those that protect large, heavily populated urban areas.

We also must discourage new development in the flood plains, unless there is a pressing need for that development and adequate protection can be provided. Population centers on the Gulf Coast must be given a higher level of protection than now most have.

ASCE believes Congress should establish an independent advisory panel to envision the future of the Gulf Coast and to rec-

commend ways to begin rebuilding of the areas that were devastated by Katrina on August 29th.

Mr. Chairman, this concludes my testimony. I will be pleased to answer any questions that you may have.

Senator VITTER. Thank you very much, Mr. Roth.

Now, Dr. Suhayda.

**STATEMENT OF JOSEPH N. SUHAYDA, Ph.D., EMERITUS
ENGINEERING PROFESSOR, LOUISIANA STATE UNIVERSITY**

Mr. SUHAYDA. Mr. Chairman, thank you very much for having me here. I have written testimony that I would like to depart from slightly, because many of the topics have been covered.

Two issues I would like to raise that I haven't heard mentioned is the current authorization being Category 3 protection I think is inadequate. We have all recognized that. I wanted to address that as an issue that I think Congress directly has responsibility for.

The second issue is interim flood protection. Much of what we heard is talking about the long-term, and these are certainly strategic issues that need to be addressed. But what are we going to do in the 10 to 15 years, or even this winter, and what can we do?

My background is, I taught at LSU in the civil engineering department for 20 years. I was at LSU for 30 years. I was a senior consultant to the New Orleans district office of the Corps of Engineers in hydrology and hydraulics. I have worked extensively with FEMA, the Office of Emergency Preparedness and the State of Louisiana and several of the levee districts. So my experience has been really at the grass roots. I am not a policy person. I have talked and given presentations to levee boards and levee districts and levee meetings, trying to inform people of the nature of the threat.

One of the things that I think has come out is that the levee system is quite complex. The hurricane, which include waves and storm surge itself was highly variable over the area. Then third, the damage that was realized was quite complicated, geographically and in terms of the types of damage that occurred. So I think initially we have to go into this with the idea that it is not a system, it is a bunch of individual things that have in and of themselves their own threats and their own capabilities to resist that threat.

So I think looking at the district level, looking at the flood district level and integrating and making sure that there is a consistency at that level, I think is a lot more reflective of the actual nature of the problem. East Jefferson Levee District, which protected Jefferson Parish, the east side of Jefferson Parish, that area was not extensively flooded. I think we need to look at that as a lesson learned. I will tell you something about how we approach that.

But as far as the current situation, we do not know if we have Category 3 protection or are going to get it by next summer, and Category 5 protection is 10, 15, 20 or greater years in the future. The first thing I would like to address is just simply the authorization that the Corps operates under. It has been repeatedly cited as the reason why the Corps can't do more for the State. We heard years ago we would like to provide Category 5 protection, but you can't afford it, and Congress hasn't authorized it. Well, Congress

needs to authorize, and not necessarily fund, but authorize the Corps to look at Category 5 protection.

Just as an example in terms of consistency, the river levees running through the city are preventive of a one in 800-year flood. The hurricane protection levees are one in 200-year flood protection, a four times greater risk. Why? Why is one side of the city protected to a four times higher level of safety over the other?

Also the current authorization is really a 1965 document. The city is different. It is obvious that things are different. The wetlands are different. We need to update our whole thinking about how to address these issues. As far as interim flood protection, what I think can be done is to not focus on the levees as exclusive flood protection mechanisms, but consider redundancy in that, we don't have to have Category 5 levees to have Category 5 protection for certain parts of our communities.

We actually could have prevented flooding of the Superdome with a structure that encircled the Superdome. We can take that principal of using interior drainage control features such as the 17th Street Canal. That is a wall, now, that bisects essentially the metropolitan area on the northern side of the Metairie Ridge. If that were used in conjunction with the Metairie Ridge, we could compartmentalize and localize the flooding, which inevitably seems to be a possibility.

In terms of St. Bernard Parish, for example, I would like to direct your attention there to where it says St. Bernard and it is pointing to the wetland area. The red line there is the Forty Arpent levee, and that is what is I think being considered as a relocation point for the hurricane protection levee, which would then put that levee behind about a mile to 2 miles of wetlands. There we are, we have wetland protection right in front of us.

Other parts of St. Bernard Parish, you can see the little red line running from the Forty Arpent levee to the River levee, would also compartmentalize the flooding that might occur in St. Bernard Parish. Maybe we could look into protecting critical infrastructure within St. Bernard Parish, such as police stations, hospitals, governmental buildings, to allow it come back to Category 5 protection, but not necessarily have to wait to protect the whole parish.

So those are the two issues I wanted to concentrate on, the technology for doing the inner protection, as has been already described, is there. We actually put 1.8 miles of flood protection on top of the East Jefferson levee district levee in July 2004, because the levees are about three feet below the design grade. The parish knew that, the Corps knew that, the emergency managers knew that we didn't have Category 3 protection. That project was accomplished in about 2 weeks, 1.8 miles.

So I think we have a number of options that should be considered. Of course, I would like to have, any questions that you have, an opportunity to answer them. Thank you very much.

Senator VITTER. Thank you, Doctor. We appreciate your comments and would note that this committee today will pass out authorization for a design for a higher standard, including Category 5. So we are certainly taking your advice in that sense.

Professor Verchick.

STATEMENT OF ROBERT R.M. VERCHICK, GAUTHIER-ST. MARTIN EMINENT SCHOLAR CHAIR IN ENVIRONMENTAL LAW, LOYOLA UNIVERSITY, NEW ORLEANS

Mr. VERCHICK. Thank you.

Mr. Chairman and Members of the committee, thanks for the opportunity to appear before you today and testify. I am an expert in environmental law and policy and a resident of New Orleans. I hold the Gauthier-St. Martin Chair in Environmental Law at Loyola University, and I am also a board member of the Center for Progressive Reform. That Center actually has drafted two different reports on Hurricane Katrina, one called, "An Unnatural Disaster," another called, "Broken Levees: Why They Failed." They are available on our Web site.

My written testimony I am going to deviate from, but I ask of course that the written testimony be incorporated into the record.

Today, I would like to focus on some of the things that we have heard already about what we know, and then move on to some policy lessons I think that we can learn from this. What we know so far, and what we have heard, essentially the things to point out are that we have the MRGO, the MRGO that funneled that surge into the heart of the city. That is one thing that we have to figure out how to take care of.

We also know that we had some levees, particularly the 17th Street and the London Avenue ones, that just broke apart. LSU is estimating that there are 20 separate breaches in those levees in part where those transition areas are. We know that historically there has been a lack of adequate maintenance and funding for the levees and of the Corps in general. We know that there is a lack of process to regularly assess levee integrity, even though we know the levees sink on their own because of subsidence.

We now have allegations from independent expert bodies of poor levee design and bad construction, and now there are even suggestions of corruption or malfeasance on the part of the Corps itself and its contractors.

The other side of this is that we know we have coastal wetlands in Louisiana, a quarter of all coastal wetlands in the United States. They are like a patient dying on the operating table and they have been for decades. We are losing 6,600 acres a year. We lost 100 square miles just because of Hurricane Katrina, and these are the buffers that are meant to protect us in times of hurricane.

Well, what can we learn? Here are some of the things I suggest, with a recommendation attached to each one. No. 1, focusing only on levees is a fool's gamble. Any new hurricane protection must be integrated and must consider simultaneously levee and gate construction, wetland restoration, habitat preservation, canal navigation, and patterns of residential and commercial development.

Levees don't protect people. Flood protection systems protect people. Those systems are made of multiple layers of defenses all working together. Some of them are natural, some are enhanced by human beings, some of them are completely artificial. You have sand bars, barrier islands, marshes, cypress swamps, levees and perhaps some day sea gates, and all of those things have to be looked at at once. There is no way you can protect the city from a Category 5 storm without the coastal wetlands.

The Dutch, who revolutionized flood control, recognized years ago that a levee strategy by itself will sink a city. That is why their flood control programs incorporate the natural features as well as the human-made features.

Also, it is cost effective. Because there are some types of protection you get by preserving and maintaining barrier islands that you wouldn't with dams or dikes.

The second point is that strong plans are adaptive plans. A new hurricane protection vision should incorporate formal mechanisms by which an independent, scientific board regularly assesses the design, condition and performance of hurricane protection features. This would effectuate the rebuilding or the raising of levees as they sink.

The third, what's good for the environment is good for hurricane protection. New hurricane protection visions must adhere to current environmental and procedural standards, including the National Environmental Policy Act. I can answer questions about that as we go.

In my last 30 seconds, the Army Corps can't do it alone. Effective hurricane protection in the Gulf may require the establishment of an independent commission made up of Federal, State and local officials, maybe something like the South Florida Ecosystem Restoration Task Force. The No. 1 reason is, we need integrated solutions that involve land use as well as other things that the Corps doesn't have primary skill with.

No. 2, we need a body that has its full attention on this ball. No. 3, the Corps is likely to be seriously distracted by ongoing civil and criminal investigations that will prohibit it from being as frank and forthcoming as it should about issues involving flood protection.

With that, I thank you and I am open for questions.

Senator VITTER. Thank you very much, Professor. We appreciate your being here.

Now we will get to questions. Dr. Zimmie, going back to the 17th Street Canal area in particular, what is the conclusion of your preliminary study on whether the conditions, including the peat layer, et cetera, that led to that failure, aren't more widespread up and down that canal, such that we need to take action beyond simply where the breach occurred, even in the short term?

Mr. ZIMMIE. That is an excellent question. I think you have hinted at it several times. They will repair that breach, and they will make that breach very strong. Then the question is, if we move away from there, do we have similar conditions. In other words, repair the 17th Avenue breach, and then another Katrina hits next year, and will a wall, say a quarter mile away, fail. That is your question. How widespread is it?

We can't really answer that question at this point. That is a big concern. The other parts of the levee system have not been tested. So you may fix, it is like a chain. You have one weak link in the chain and the whole chain has failed.

So now you have another link further down. You fix one link and then the next link fails.

Senator VITTER. Specifically, do you all have any conclusions about how widespread this porous peat layer is, assuming that is a significant factor?

Mr. ZIMMIE. I suspect, peat is very common in the New Orleans area. I don't think there is any question about that. We have seen many cross-sections that the Corps provided us, and peat is found throughout the New Orleans area. Is that any surprise? It is a swampy area. So of course there is peat. The question is, how widespread is it? I think that is what the Corps is trying to answer now. They are going along taking samples.

We talked about the normal being 300 meters apart. It is an economic decision. You can't poke a hole in the ground every 10 feet. It is just not feasible. So the question is, how much soil sampling do you do. So I don't think we know the answer at this point in the game.

Am I worried about it? Yes, I certainly am. I think if they just fix the breaches and just repair what is happening and then Katrina comes along, I think you will probably have another part that will fail. I think that is your concern. I think with the investigation, securing soil samples, getting more information to do a proper design should be able to answer that.

Senator VITTER. Dr. Gagliano, in areas where levees cross these faults, what can be done to counteract the negative effects of that?

Mr. GAGLIANO. It is going to vary somewhat. The character of the fault zone varies. In some places the actual plane of the fault movement is pencil-line thin. In others it may be a zone of several hundred feet or more wide that would consist of broken clay particles and sand lenses and things of that sort. In each instance, however, we have documented vertical movement of fluids, primarily salt-water and gases, from these decaying organic materials that underlie the area.

The bases of the faults are very deep, like 25,000 feet. So clearly, we can't drive sheet piling down 25,000 feet. But the risk of those fault plains allowing water to move and seep under the levees is only as great as the water body that we are trying to contain. So we are on the right track by driving deeper sheet pilings.

The other factor is, in the greater New Orleans area, the real foundation-bearing horizon is the top of the Pleistocene formation, which is about 75 feet deep. So our first consideration would be to make sure that where we use sheet pilings, we anchor those into more solid material.

If I could comment on the question you asked Dr. Zimmie, we really have great detailed knowledge of the distribution of peats and buried sand bodies in the New Orleans area from literally thousands of shallow borings that have been conducted and geological studies that have been conducted over the years.

Geotechnical studies tend to be along lines and done primarily to provide samples for laboratory analysis. We need to crank more geology into that interpretation.

Senator VITTER. Thank you.

Senator Jeffords.

Senator JEFFORDS. Thank you, Mr. Chairman.

For those of you on this panel impacted personally by the storm, I want to express my sympathy. I have been focused throughout our committee's work on Katrina on the question of why do we need flood control in southern Louisiana. We have heard a lot about people of this region of the country and the unique culture

of the region. I will never get tired of hearing more about the treasures of southern Louisiana, and I invite each of the members of this panel from Louisiana to answer this question.

Why do we need to preserve the culture and the people of southern Louisiana with good flood control? Mr. Gagliano?

Mr. GAGLIANO. Thank you for that question, Senator. I am a native of Louisiana, born in New Orleans, and I love the place. I love our culture, I love our landscape. People live in coastal lowlands and deltas all over the world. The Dutch have mastered the business of living in a deltaic area, and have the most densely populated area in Western Europe. No one would question whether or not the Dutch people and their culture should be protected by adequate levees and drainage systems.

In Louisiana, our population density is less than that of the Netherlands. But when European colonists settled our area they recognized that this was a deltaic lowland. They selected the highest ridges for the location of cities and communities and the highest ridges for agricultural pursuits. We have extended these land uses into areas that require flood protection and drainage.

The area was settled because of its strategic location and abundance of resources. We are now in the business of using the land and its resources for the benefit of the State and the Nation. Without a doubt, Louisiana is a net producer of resources. It is an environmentally rich area, it is an area that produces oil and gas, agricultural products and fisheries. It has the largest port in the Nation, a rich cultural heritage, and on and on. I would hope that the Nation will recognize the need to allow us to continue providing these values and services.

Thank you, sir.

Senator JEFFORDS. Thank you. Mr. Suhayda.

Mr. SUHAYDA. Yes, I have a list here, I will go over them real quickly. These have been identified as part of the case that the State has tried to make for preserving our wetlands.

But in particular, the ecosystem that we are dealing with is unique. It is the largest wetland system, very productive, provides a lot of recreational opportunities. So losing the wetlands, which is part of our overall strategy to prevent, I think would definitely be a loss to the country.

Energy, for example, the State supports and is one of the most aggressive States in working with the Federal Government to exploit energy resources. There are consequences to that. They may not have dominated our wetland loss problems, but they are certainly a factor such that we have paid a price and we are in a sense suffering some of the consequences of allowing navigation development and energy development to take place.

We are a gateway to South and Central America. International trade and global economy is growing, and in spite of the recent little speed bumps that we hit with South America, I think we can expect to see that to be a focus of the Federal Government for years to come.

We have the largest port activity by volume in the United States in the Mississippi River corridor that is supported by the culture and the economic activities in southern Louisiana. Culturally, I think historically New Orleans was an entry port for immigrants

for years and years. We have a mixture of historical architecture and cultural issues and food and all the other things that are not to be found any place.

So I think real quickly, those are the types of things that come off the top of my head that make the southern part of Louisiana valuable to the country and worth saving in the broadest context of what you described, flood protection and environmental restoration.

Senator JEFFORDS. Professor Verchick.

Mr. VERCHICK. I can't improve on that. I think that is all absolutely right. New Orleans is a city that I love and which thousands of visitors do every year. It is a cultural gem in the world, just like Venice, which again is having to master its own sort of environmental issues and economics. The port activity, the offshore oil, a fifth of all the fish that we eat in the United States comes from the Gulf, which is supported by those wetlands. It produces billions in nature's services, ecosystem services down in that area. It can be preserved with the engineering, and it should be.

Senator JEFFORDS. Thank you.

Senator VITTER. Thank you, Senator.

Mr. Roth, you had mentioned at one point some relatively modest and simple and inexpensive add-ons that can greatly reinforce the existing levee system. I think one of the main things you were thinking of is scour protection on the land side of levees, and the Corps has mentioned that for the Industrial Canal in particular. Do you have an opinion about how adequate that will be on the land side of the Industrial Canal to the existing eyewall to provide greater strength in the case of overtopping?

Mr. ROTH. I was glad that Mr. Hitchings brought diagrams to effectively show in pictures what we are trying to describe. I think that as a scour protection, if properly constructed on the inside, will provide a great deal of protection for overtopping in the event of a future storm.

Senator VITTER. With that in mind, with that scour protection, are you concerned that the new inverted T design is only being applied, at least as of now, in a limited area of the breach?

Mr. ROTH. I think we have to consider your question to Dr. Zimmie. We need to be assessing the geologic conditions using the data and information that Dr. Gagliano has referred to. In addition, we need to be taking additional soil borings and Cohen penetrometer testings throughout the levee system to see if we can identify other perhaps isolated areas where the soil conditions are such that it causes that particular section of wall to be in jeopardy.

But first of all, we really need to understand exactly how or if the peat truly contributed to the failure. That is the whole purpose of the IPET investigation. We think we have a fairly good understanding of how things failed. I can appreciate your frustration, Senator Vitter. We don't yet know exactly why things failed. I think that is a good illustration. If we made a poor assumption about why a particular levee failed and then went and spent a great deal of money to reinforce other levee sections and then later found out that that was not really a contributing factor to the failure, we would have perhaps wasted some resources that could be

better used to increase flood and hurricane protection in other matters.

So I think we really need to understand the mechanisms of the failure, and we need to look to see if those conditions and those mechanisms occur elsewhere. If that is the case, then more robust systems such as the T walls are definitely merited.

Senator VITTER. With that in mind, at the Industrial Canal, not 17th Street, but the Industrial Canal, isn't it a fair consensus at this point that the cause was overtopping and scouring on the land side?

Mr. ROTH. I believe so, yes.

Senator VITTER. Assuming that cause, how adequate is the scour protection to avoid that in the future versus a whole new wall design like the inverted T everywhere?

Mr. ROTH. I think there are a number of factors that need to be considered. We certainly need to look at the scour issues. We need to look at the conditions and the IPET will be examining the hydraulic modeling to determine the wave heights and the potential surge heights. So we will have a much better understanding of where these things possibly can occur.

There is another factor that we can take into consideration as well, and that is, if there is going to be a storm surge that does cause overtopping, perhaps we could direct some of that overtopping to preferential areas where we know that the wall is going to behave much better. It is like a fuse plug is often built into small dams. That is a preferred failure mode that in the event you get a high flood, the fuse erodes quickly, but it prevent greater damage to the main structure.

So I think some preferential overtopping needs to be considered in the design. I know there are a number of other factors that the Corps is going to be looking at.

Senator VITTER. Dr. Suhayda, do you have any comments in particular about the immediate term and what the Corps is doing now until June? What should we consider doing differently, particularly in the short term?

Mr. SUHAYDA. Well, the reason I brought that up is I think it has been neglected. I haven't heard anyone talk about localized flood protection that will allow the communities to start to recover. The whole issue here is not engineering. It is community development, economic development and protecting people and property.

If the Corps and the Federal Government can advance that along the lines of the levee issues, that is fine. I think that is incomplete. I think we need to be looking at protecting infrastructure that would be critical to recovery. It may be years before the levee systems are able to do that. Yet we need to have those online.

The idea of a fuse, for example, my reaction to that was when a fuse blows, the lights go out. We have to have some way of dealing with interior flood management. Levees are susceptible to failure. So our thinking now, I think, should be to look at how we can manage floodwaters that should get through the Federal levee. Maybe that is not a Federal responsibility at this point.

But once the water got through the 17th Street Canal, it flooded all the way to the Superdome, miles away. But it did not get to East Jefferson Parish because of the Metairie Ridge. So we can take

advantage of some of these things that are clearly outside of the box of current thinking with regard to focusing on the Corps of Engineers' responsibility and their authorizations for perimeter levee protection. I am just saying, we are neglecting other opportunities.

Senator VITTER. Senator?

Senator JEFFORDS. Professor Verchick, periodically on this committee we hear discussion of the role of environmental litigation on the selection of floodwall and levee designs along the lake. Can you comment on this?

Mr. VERCHICK. I would like to, actually. There was an op-ed early on from the Wall Street Journal and there has also been testimony before the House Committee on Resources suggesting in particular that one environmental lawsuit drowned New Orleans. That is simply false, and I will tell you a little bit about that.

If anything drowned New Orleans, it is likely to have been the design and construction of the levees. In 1965, Congress authorized what was called the Lake Pontchartrain Vicinity Hurricane Protection Project, which was a project by which the Corps had two options: one to build high grade levees, and the other was to build a kind of a sea gate that would contain Lake Pontchartrain, so the water wouldn't surge in there. That was called the Barrier Option.

Well, the Corps at that time chose a barrier option, but it didn't have a very big environmental impact statement, which was required in the 1970's after the National Environmental Policy Act. They had flow models that were 10 years out of date, they had biological analyses based on a single phone call from a marine biologist. It was very skimpy. There was nothing to the EIS.

So a group of fishermen and an environmental group sued, simply saying, we want a proper environmental impact statement. Well, it went to the Federal courts. In 1977, a Federal court said, "You know, if you want to build something, Corps, come back with an environmental impact statement that is proper." It happened all the time in those days. The Corps routinely came back with a proper EIS.

But in this case, they didn't. In this case they looked it over again and they decided on their own that the Barrier Project was too expensive, mainly because it required condemning a lot of land that was privately owned for the gates to work. So they chose the high levee option, which was probably the right option, although I am not an engineer. Because it was an option that could have protected us, to some degree, against Katrina, if the levees had not given way.

So they said, themselves, that they did it because it was less expensive and because it was a better option for protecting all of the lake. So the buck stops with the Army Corps of Engineers. It was not a group of rag-tag environmentalists that defeated the will of the U.S. Army in this case. The thing to understand is that since these hurricanes, the U.S. GAO and the Chief of Engineers has testified before Congress, saying that those sea gates would not have helped, and probably would have caused more damage.

The reason is those sea gates did close off, would have closed off part of Lake Pontchartrain. But the water came through MRGO, through the Mississippi River Gulf Outlet. That shot the water

right into the heart of the city, an end run around any barriers that would have been built.

So that is my version, and the true version of how environmental litigation is related to these barriers. If anything, those sorts of lawsuits help government make better decisions. Because in this case, it did force the Corps to go back and think about all of the options it had when choosing a system.

Senator JEFFORDS. Mr. Roth, can you describe why you think a national levee safety program is important, and why the current inspection system is not adequate?

Mr. ROTH. I think Dr. Zimmie alluded to it in one of his responses, that there are literally thousands and thousands of miles of levees in the United States. Almost all of them fall under a variety of different jurisdictions. Many of them were built many, many years ago, before modern design standards had been in place. Really quite, just like occurred in New Orleans, until a natural disaster does occur, many times features like levees or dams are out of sight, out of mind. We don't think about them until there is a problem associated with them.

In fact, they are a very important part of our infrastructure. In fact, they need to be maintained and periodically evaluated. We need to periodically check them to make sure that they are adequate as our knowledge of hydrology and natural disasters improves, and as we recognize that these are a very critical part of defense against hurricanes and floods in particular parts of the country.

We believe that we need a national policy regarding these. We point to the National Dam Safety Act. The National Dam Safety Act was enacted about 30 years ago, I believe, following a series of dam disasters in the 1970's. Since that time, we have gotten a much better handle on dams that are unsafe. We have improved the general public health, safety and welfare by having a knowledge of those unsafe dams and then taking steps to make them, either take them out of commission or improve their safety and their performance.

We believe the same thing needs to be done for levees. It is a national issue, it is a national problem. The levees ought to be designed to national standards. We need many things that such a levee program would provide, not the least of which is just an inventory, so that we know how many there are and in what condition they exist in.

Senator JEFFORDS. Thank you. Thank you, Mr. Chairman.

Senator VITTER. Thank you very much. Thanks to all of you for your very valuable testimony and your ongoing work. We appreciate it.

Now to wrap up the hearing, I would like to invite, as I promised, Mr. Hitchings back, if he has any reactions or comments regarding this other testimony.

Mr. HITCHINGS. Thank you, Senator Vitter. Just a couple of points.

I do want to reiterate the Corps' concern as you have expressed for the vulnerability of the system after we make those emergency repairs that we are doing under the Flood Control and Coastal Emergency's authority. Our risk and reliability study that we are

conducting as part of the IPET is really focused to identify those potential problems that are still remaining that need to be addressed. We have started that effort now and we will get the results of that just absolutely as quickly as we can.

It is critically important and also important that you can't make some conclusions without adequate data and analysis in that particular area.

I would also like to correct one statement that was made earlier, I believe it related to the previously proposed Barrier Plan, in that it would not have made any difference. That statement I believe was accurate, but it is accurate not because it was an inadequate plan, and not because the storms would have gone up the MRGO anyway. It would not have made any difference because its authorized level was still the standard project hurricane. All indications are that Hurricane Katrina exceeded that level.

So if a Barrier Plan or any other alternate plan would have been put forward and that would have been constructed, it still would have been overwhelmed by the forces of Hurricane Katrina.

So subject to any additional questions, that is all I have to add, sir.

Senator VITTER. Well, certainly to underscore some of my earlier comments, we are very eager to hear the Corps' conclusions within the next month about things like soil samples, the condition and types of soil in different places like the 17th Street Canal, what does that mean in terms of addressing the canal walls on either side of the breach, in fact, on the other side of the canal, how adequate the anti-scouring fix will be on the Industrial Canal, since you are not putting an inverted T everywhere.

So this has to be an ongoing discussion and conversation. We need to reach some of those conclusions pretty quickly in order to do some things that are adequate for next hurricane season. So I will look forward to that.

Mr. HITCHINGS. Absolutely.

Senator VITTER. Thank you very much. With that, the hearing is adjourned.

[Whereupon, at 11:35 a.m., the committee was adjourned.]

[Additional statements submitted for the record follow.]

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM THE STATE OF ALASKA

Thank you, Mr. Chairman. All Americans can appreciate the committee's work on this important subject. I will be very brief.

I want to go on record in support of the purpose behind this hearing, because it is critical that we learn from the mistakes of the past. It is clear that the levees in and around New Orleans were not up to their task. The political and economic causes for that failure will be debated for a long time. But the mechanical causes are already becoming clear, and the immediate concern is the need to ensure that we prevent the same failures from being repeated in the future.

If we are to rebuild the city, we must also rebuild its protections. If we are to do so with Federal money, we must do so in a way that will make the use of Americans' tax dollars meaningful. Anything else would be criminal.

It has been suggested that we need to empanel additional advisors for the Corps of Engineers. Frankly, Mr. Chairman, while I agree that an integrated, interdisciplinary approach is probably needed, I also believe firmly that it is also important to have "a place where the buck stops."

We are all familiar with the motto President Truman kept on his desk. We all know what happens when we exercise "design by committee." I respect the views of those who feel an independent oversight group is needed. Personally, I may even be in agreement.

But I also want to remind my colleagues that when disasters strike, there is often a call to bring in the military and it's not because we want a committee. It's because we know there's a need for a clear, unquestioned chain of command with the ability to see what's needed, give an order, and have it obeyed.

Mr. Chairman, I think there's a corollary in construction, especially where we are dealing with critical facilities that mean life and death to entire communities. Committees are not accountable, but individuals can be and our job is to ensure that they are. We need strong leadership with the determination to do the job right, without cutting corners, and with the courage to speak out if the resources available are insufficient for the task.

In the long run, Americans will support rebuilding but only if their money is not wasted.

STATEMENT OF DANIEL HITCHINGS, P.E., REGIONAL BUSINESS DIRECTOR, MISSISSIPPI VALLEY DIVISION, U.S. ARMY CORPS OF ENGINEERS, DEPARTMENT OF THE ARMY

INTRODUCTION

Mr. Chairman and distinguished Members of the Committee, I am Mr. Daniel Hitchings, Regional Business Director for the Mississippi Valley Division, U. S. Army Corps of Engineers. I am honored to be testifying before your Committee today, on the efforts by the Corps of Engineers to incorporate forensic findings into our ongoing repair of the storm damage reduction projects in the New Orleans area.

REPAIRS TO THE EXISTING SYSTEM

With our contractors, we are working around the clock on the levees and floodwalls to reduce the risk of damage through the remainder of this hurricane season, which continues until the end of November, and the rainy season that the area normally experiences in December and January. Our goal is to complete this phase of the effort before the start of the next hurricane season, which begins in June 2006. Our teams are actively gathering data and information from the recent storms, and we have also begun an after action assessment of the existing storm damage reduction system.

INVESTIGATING THE PERFORMANCE OF THE EXISTING SYSTEM

The Corps takes its responsibility for the safety and well-being of the Nation's citizens very seriously. In the case of the New Orleans area, we are determined to learn what failed, how it failed, why it failed, and to recommend ways to reduce the risk of failure in the future. There is no single answer to the question as to why there were failures in the storm damage reduction system, as there were multiple breaches of levees and floodwalls at a number of locations and the failure mechanism or mechanisms are likely to vary. The answer to this will follow from a thorough analysis of the data we are now collecting. In some cases, e.g., the Inner Harbor Navigation Canal, we have observed evidence of overtopping. In other cases, e.g., the 17th Street Canal, we have observed evidence of massive soil movement. The physical processes that caused the breaches will be determined from the comprehensive analysis of the data that we are collecting. What we have to date is evidence of what happened; we can see the final result of the structural behavior, but we cannot yet determine why. That will require more understanding of the design intent of each structure, its condition prior to the storm, the forces to which it was subjected (static and dynamic) and how we would expect it to respond to those forces. This is the objective of our current interagency analysis efforts. Understanding why this happened will also help us to develop recommendations on ways to reduce the risk of failure in the future.

The Chief of Engineers, Lieutenant General Carl A. Strock has commissioned an Interagency Performance Evaluation Task Force (IPET) to conduct an engineering evaluation. The IPET includes engineers and scientists from the Engineer Research and Development Center from Vicksburg, Mississippi, the Institute for Water Resources in Alexandria, VA, numerous universities, and the private sector, as well as from other Federal agencies, such as the Bureau of Reclamation and the National Oceanic and Atmospheric Administration. As the team deployed, the American Society of Civil Engineers and a University of California team sponsored by the National Science Foundation approached the Corps about similar studies of infrastructure performance they were undertaking in hopes of applying lessons learned to the levee systems in California. In the spirit openness and full transparency, we invited them to join our team beginning on September 29, 2005, for inspections of the projects involved. On September 30, 2005, we learned that the State of Louisiana

would soon establish its own study team and the researchers from the Louisiana State University Hurricane Research Center were invited to join our team in advance of this official establishment. The Corps gratefully acknowledges the assistance provided by these teams in the collection of the data.

The data collection teams have been performing field work in the New Orleans area to obtain as much data as possible related to the performance of the levees and floodwalls and to ensure that data is collected before it is covered over or lost by cleanup or as a result of repair efforts. They have been diligently recording the damages and measuring the post-Katrina conditions. They have examined physical evidence to establish the maximum water elevations at various locations. To establish the timeline of events, they have conducted detailed interviews with about 70 people who sat out the storm. To establish the soil properties, they have pushed a state of the art instrumented cone to a depth of 80 feet at 56 locations. They further collected samples of the soil at depth in 10 locations. They have also electronically scanned boxes of documents dealing with the design, construction, and maintenance of the projects involved.

Over the next 8 months, the IPET will examine and analyze the data and rationally test various hypotheses about the behavior of the infrastructure. Through a thorough analysis of the data that we are collecting, we will explore whether human error played any role in the performance of the infrastructure. The IPET will use collected data, laboratory testing, and modeling activities in its analysis. The work currently planned includes providing an updated and accurate vertical geodetic datum, performing storm surge and wave modeling; determining the hydrodynamic forces created by the storm, analyzing the floodwall and levee performance when subjected to these forces; conducting interior drainage/flooding modeling to include pumping station performance; and conducting a consequence analysis and a risk and reliability assessment.

The American Society of Civil Engineers (ASCE) is supporting our efforts with an External Review Panel, which will provide an independent oversight of the IPET evaluation. The final IPET report will be released in June 2006. However, any important findings will be shared on an ongoing basis before then with those who are involved in the repair of the existing New Orleans levees and floodwalls.

We are making all findings available to the public and invite the public and the scientific and engineering community to share any information they may have. On October 29, the Corps began releasing available data by posting it on a publicly accessible Web site, <https://ipet.wes.army.mil>. Additional data will be added to the Web site as it becomes available. The IPET is collecting pre-Katrina documentation (design and construction drawings, soil sample records, etc.), post-Katrina documentation (hydrographic surveys, soil samples, concrete cores, etc.) and other performance data (eyewitness accounts, photographs, etc.). The data being released includes design memorandums dating back to the 1960s, and the associated reports for the Lake Pontchartrain, Louisiana and Vicinity High Level Plan, which includes the 17th Street Outfall Canal and the London Avenue Outfall Canal. This information includes the project plan, hydrology and hydraulics, geology, foundation investigation and design (including the field exploration, soil borings, and laboratory testing) and the structural design.

In addition to the IPET effort, the Secretary of Defense has directed the Secretary of the Army to convene an independent panel of national experts under the direction of the National Academies to evaluate the performance of the storm damage reduction system in New Orleans and the surrounding areas. The National Academies is assembling a multidisciplinary (e.g., engineering, atmospheric sciences, etc.) panel drawn from the public and private sectors and academia.

The National Academies Panel will perform a high-level review and issue findings and recommendations based primarily but not solely on the data gathered by the IPET and the ASCE Independent Review Panel. The findings of the National Academies Panel will be subject to a peer review process before being released under the imprimatur of the National Academies.

The National Academies Panel will produce a forensic study that focuses on the existing levees and/or floodwalls that were overtopped, breached, or failed during Hurricane Katrina, and whether such situations were the result of design, construction, or operation and maintenance issues, soil and geo-technical conditions, changed assumptions upon which the design or construction were based, the severity of Hurricane Katrina, or other factors. The National Academies Panel is expected to produce its final report by July 2006. All reports generated by these panels will be made available to the public.

COORDINATION OF POST-STORM ANALYSES WITH ONGOING REPAIR EFFORTS

Until we can collect and analyze all the physical evidence, we will not have a complete picture of what happened. The results of our study will provide a better indication of the extent to which the existing system can be expected to reduce the risk of future storm damage. We will be examining and providing analysis on the performance of the entire storm damage reduction system, to understand the failures that occurred, to understand other components of the system that may have been degraded in their capacity to protect against future storms and to understand where the system performed successfully. We will be developing information on risk and reliability of the system as it will be following the current repairs. Nevertheless, I want to emphasize that we do not need to wait until the study is complete to begin applying what we learn. As we learn we will immediately act to incorporate those findings into the work in which we are engaged. In the interim, results are being shared on an ongoing basis with the team responsible for the repair of the existing levees and floodwalls.

As the data collection teams have been completing their work, they have been convening exit briefings with representatives of the New Orleans District. This week, the team charged with the repair of the existing system, identified as Task Force Guardian, will be provided with a formal summary report with recommendations to improve the system's performance based on the information collected and analyzed to date. The team is already at work increasing the depth of sheet piling and providing armor stone protection in some areas. The summary report will be made available on the publicly accessible Web site.

This concludes my statement. Again, I appreciate the opportunity to testify today. I would be pleased to answer any questions you may have.

STATEMENT OF THOMAS F. ZIMMIE, PROFESSOR AND ACTING CHAIR OF CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT, RENSSELAER POLYTECHNIC INSTITUTE

My name is Thomas Zimmie, and I am a Professor of Civil and Environmental Engineering and the Acting Chair of the Civil and Environmental Engineering Department at Rensselaer Polytechnic Institute (RPI) in Troy, NY. I have a PhD in Civil Engineering, am a licensed professional engineer, and my specialty area of practice is geotechnical engineering. I have about 40 years of professional experience.

I was a member of a National Science Foundation sponsored investigative team that was formed to investigate the levee failures in the New Orleans area, caused by Hurricane Katrina on August 29, 2005. As a result of the investigation a report was produced containing the observations and findings of a joint investigation between independent teams of professional engineers with a wide array of expertise.

Any opinions I express here today are mine alone and do not necessarily reflect the views of the National Science Foundation or any other group or agency.

The report "Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina on August 29, 2005" was dated November 2, 2005 and was presented to the Senate Homeland Security Committee. A second version of the report is being finalized. However there are only minor changes from the original report.

The investigative teams spent much of October 2005 in the New Orleans area visiting the levee system. I was in the New Orleans area for about a week in the middle of October, visiting miles of levees, including the highly publicized levee breaches such as the 17th Street Canal, London Avenue Canal and the Industrial Canal.

There is not one simple answer as to why the levees failed. Field observations indicated various causes: overtopping of the levees, erosion, failure in foundation soils underlying the levees, seepage through the soils under the levees causing piping failures, and this is not a complete list.

It was a pleasure and an honor to be a member of the investigative team, although at the same time it was a sobering and sad experience to see the damage to life and property caused by Katrina.

Hopefully the results of our study will lead to a clear appreciation of what happened in Katrina, and that the lessons learned from this event will lead to improved protection in the future, not just in the New Orleans area, but throughout the Nation and around the world.

I consider it an honor and a privilege to appear before this committee, and hope I can be of assistance.

RESPONSES BY THOMAS F. ZIMMIE TO ADDITIONAL QUESTIONS FROM SENATOR VITTER

Question 1. On the Industrial Canal, the Corps has determined to use a different design to replace the floodwall that failed. At this time, I understand that they do not intend to replace the remaining floodwall. Based upon the preliminary reports, it seems that this may be a mistake. What standard should the Corps use to determine when to improve versus replace a design that failed?

Response. The repaired sections of the Industrial Canal should be even stronger than the original floodwall, since they will consist of embankment levees at about the same top elevation as the original walls, with additional sheet piles driven on the canal side of the embankments. The determination of when to improve versus replace a design that failed utilizes sound engineering practice and judgment. When a failure occurs, the cause of the failure must be determined. We learn through failures how to improve our designs and prevent future failures. The Corps is carrying out investigations to determine the causes of the levee failures; including subsurface investigations, soil sampling and testing, and computer and physical modeling of the levees. I am confident that as a result of these investigations the causes of the levee failures will be determined, which in turn will lead to improved levee designs and construction. That is, safer and stronger levees.

Question 2. Do you believe that there are problems with using different designs on the same floodwall? Specifically, do these additional transitions establish additional "weak links" in the system?

Response. Transitions between different types of floodwalls can be a problem, and indeed did cause problems during Hurricane Katrina. This was pointed out in the NSF/ASCE sponsored report dated November 17, 2005, dealing with the performance of the levees. The Corps is well aware of these types of problems.

There are several main types of designs utilized for the New Orleans flood protection system: for example, earth levees, concrete walls, and sheet piles. Thus there are numerous transitions in the several hundred miles of levees in the system. The real problem was not the transitions between different designs (with a few exceptions), but transitions such as road cuts, railway cuts, floodwalls and similar. We saw several places where sandbags were to be placed in these openings but the sandbags were never placed. Some floodwalls were never closed, and in at least one case we observed, the floodwall was damaged and could not be closed. This is a serious problem, and a problem of levee management and logistics. It must be addressed. After all, what good is the best levee system if floodwalls are not closed and gaps remain open during floods.

Question 3. With our unique geography and geology, is it possible to provide protection from a Category 5 storm surge in south Louisiana?

Response. There is absolutely no question in my mind that the New Orleans flood protection system can be improved to provide protection from a Category 5 storm surge, from a technical standpoint. The flood protection system for the Netherlands is an excellent example of a very complex and expensive system, and is probably the best in the world.

However such improvements in the New Orleans system will not be simple, nor inexpensive. It would take many years to construct such a system, and likely hundreds of billions of dollars. Will the resources be provided to construct such a system? An excellent question. Should the resources be provided? In my opinion, yes.

Question 4. You used to work for the Corps. Do you believe that the current project process should be modified for efficiency? How?

Response. Although I have never worked as a civilian for the Corps I was a U.S. Army Corps of Engineer Officer (combat engineer), and as an engineering professor have often worked with Corps research laboratories, mostly Vicksburg and the Cold Regions Lab in Hanover, NH. I have a great deal of respect and confidence in the Corps. It appears they have been given a considerable amount of resources to carry out the levee investigations and reconstruction. Thus I feel confident they have the capability to do a good job. A potential problem is the tight schedule. Can the flood protection system be repaired in time for the next hurricane season? I am in no position to answer that question. However from the anecdotal evidence I have gathered by talking to designers, contractors and the Corps, everyone is working hard to achieve the goal, and the general attitude seems very positive. I am optimistic the deadline will be met.

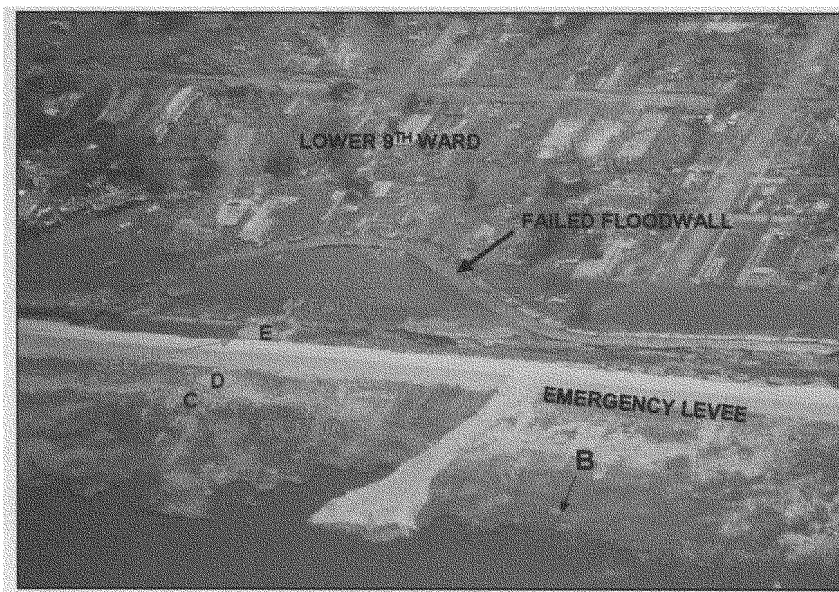
STATEMENT OF SHERWOOD M. GAGLIANO, PH.D.,¹ PRESIDENT, COASTAL ENVIRONMENTS, INC.

EXECUTIVE SUMMARY

During Hurricane Katrina, a number of breaches occurred in hurricane levees and floodwalls in southeastern Louisiana in locations where the structures were built across deep-seated geological faults. Fault related breaches along the 17th Street Canal, the London Avenue Canal, and the Inner Harbor Navigation Canal in the Greater New Orleans area caused flooding in densely populated urban areas resulting in catastrophic loss of life and property. Along the Mississippi River below the City of New Orleans in Plaquemines Parish, flood levees were breached as storm surge moved up the river channel. In addition, levees in the vicinity of Montegut, south of Houma, Louisiana were also breached. At many, if not most, of these locales major regional geological faults are known to underlie the levees.

Recent studies indicate that ancient deep-seated regional faults, long-believed to be dormant, have exhibited surface movement during the past 50 years. Some of these faults extend down 25,000 feet and have been active for 100 million years or more. Fault planes and fault plane zones are deep cracks that result in poor foundation conditions where they reach the surface. The fault planes and zones are conduits of fluid and gas movement which contribute to poor foundation conditions. The active faults are part of a linked tectonic system that underlies the region. Most fault movement within this system is driven by natural geological processes. The fault system is an expression of, a massive "continental margin gravity slump" extending from the latitude of New Orleans to the deep waters of the Gulf of Mexico. The faults underlying the levees are elements of the linked tectonic system within this slump.

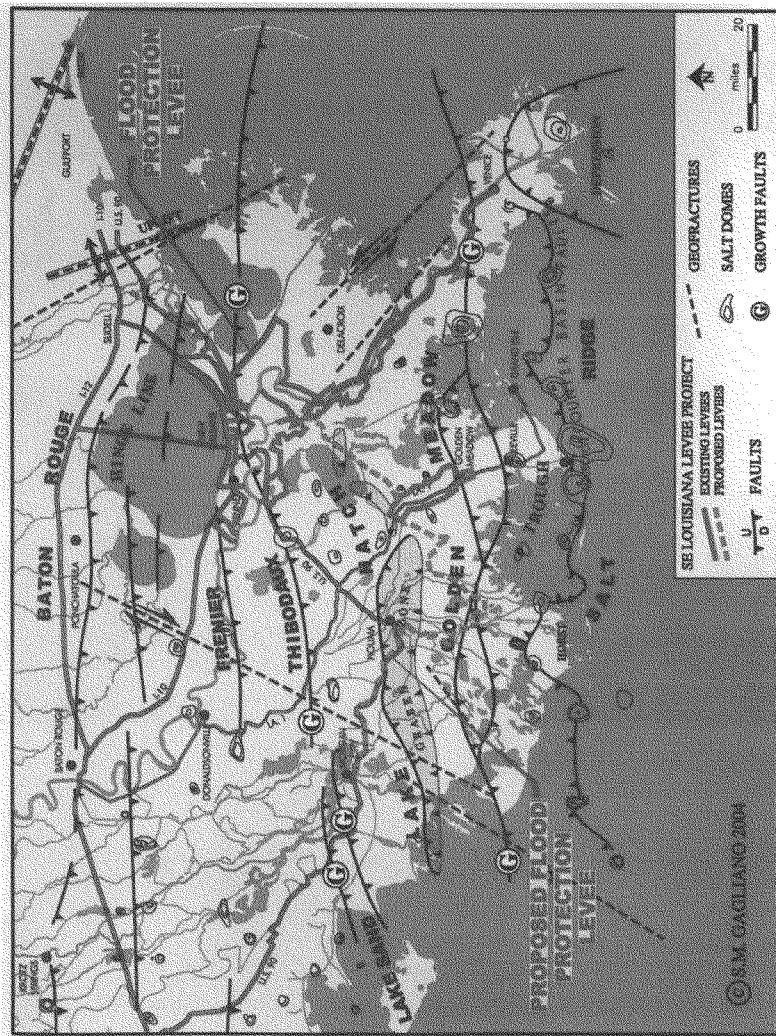
Fault hazards were not recognized at the time of the levee design and construction, but are now known to pose a significant natural hazard. The fault hazards are not insurmountable obstacles to the restoration and maintenance of a sustainable coastal zone in Louisiana, but must be a primary consideration in planning, and design of all aspects and elements of the restoration effort. All existing and proposed levee alignments in south Louisiana should be evaluated for potential fault hazards.



¹President of Coastal Environments, Inc., 1260 Main Street, Baton Rouge, LA 70802. Dr. Gagliano is a coastal geologist and environmental scientist. He received formal training at Louisiana State University and has over 40 years of coastal research experience in Louisiana and other parts of the world.

INTRODUCTION

Hurricane Katrina slammed into the northern Gulf of Mexico coast on August 29, 2005, exposing numerous low and weak spots in the levee system surrounding New Orleans and other southeastern Louisiana communities. In some areas the levees were overtopped by elevated water and/or wind-driven surge, but in other places in the Greater New Orleans (GNO) area breaches occurred along navigation and drainage canals causing flood devastation to densely populated inner-city neighborhoods. Some, if not most, of the breaches that occurred are in places where the levees were built across geological faults. This statement focuses on failures where there is an apparent relationship to faulting, a largely overlooked natural hazard. Figure 1 shows the spatial relationship between existing and proposed levee alignments and major geological faults in southeastern Louisiana. Figure 2 shows the locations of the Hurricane Katrina levee and floodwall breaches in the GNO area.



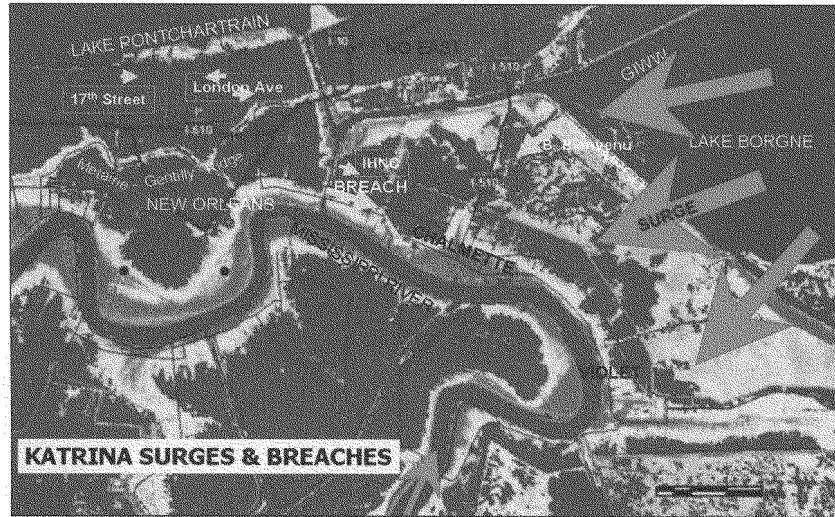


Figure 2. Location of levee and floodwall breaches that occurred during Hurricane Katrina in the Greater New Orleans area. Backdrop is a satellite image showing extent of flooding.

I have conducted field inspections at the breach sites in the GNO area, but have not had an opportunity to conduct detailed site-specific study. However, the findings and interpretations presented in this statement are based on a 5-year research effort regarding fault movement and resulting landform change in south Louisiana and southeast Texas. Results of the work have been published in geological journals, engineering journals and technical reports and have been presented at numerous meetings of professional associations and public bodies. For additional information on fault hazards see Publications at www.coastalenv.com.

FAULTS AND THE TECTONIC FRAMEWORK

South Louisiana is underlain by a maze of faults, which are known primarily from information gathered during a century of exploration for oil and gas. Most of these east-west trending features are classified as growth faults because the sedimentary beds cut by the faults are usually thicker on the down-dropped block, indicating that the faults moved during deposition. The faults are components of a regional linked tectonic framework that has been in motion for more than 100 million years and is still moving. Many subsurface faults within this system have been correlated with surface faults (Figure 3). Characteristics of growth faults are shown in Figure 4, and surface effects of their movement on landforms and near-surface deposits are shown diagrammatically in Figure 5.

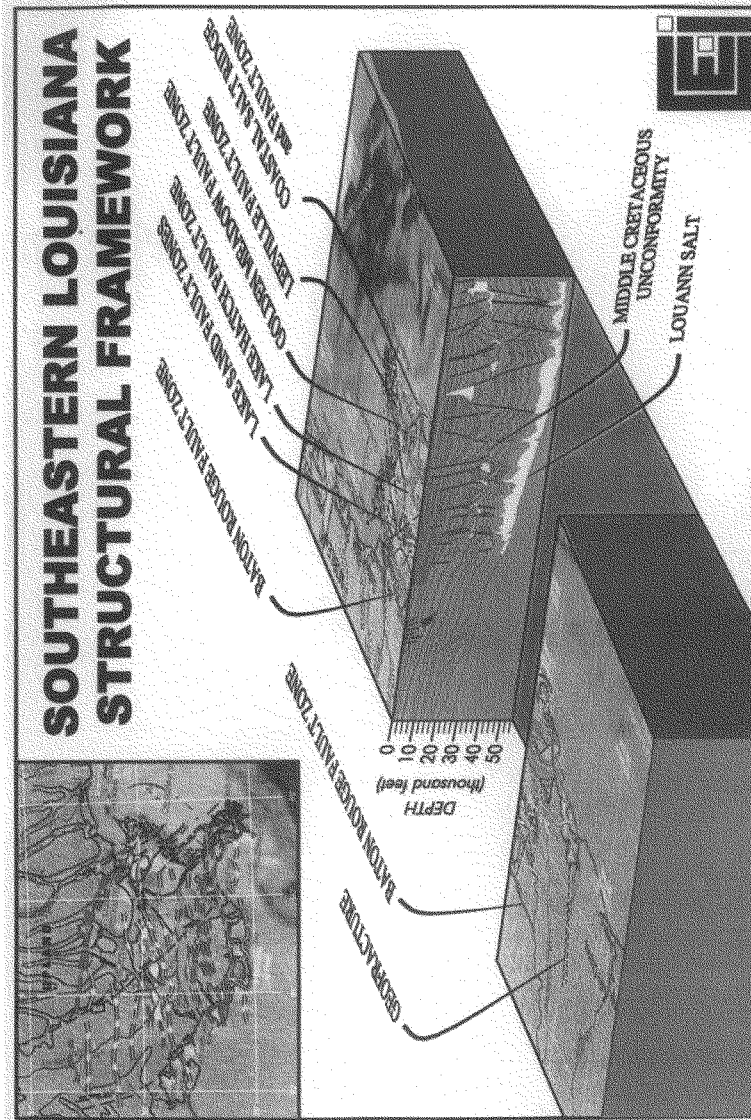


Figure 3. Active surface faults have been correlated with ancient deep-seated faults. Southeastern Louisiana overlies a deep, sediment filled structural trough, the bottom of which is 35,000 to 50,000 feet below the surface. The bases of active faults in the GNO area are 25,000 to 30,000 feet below the surface.

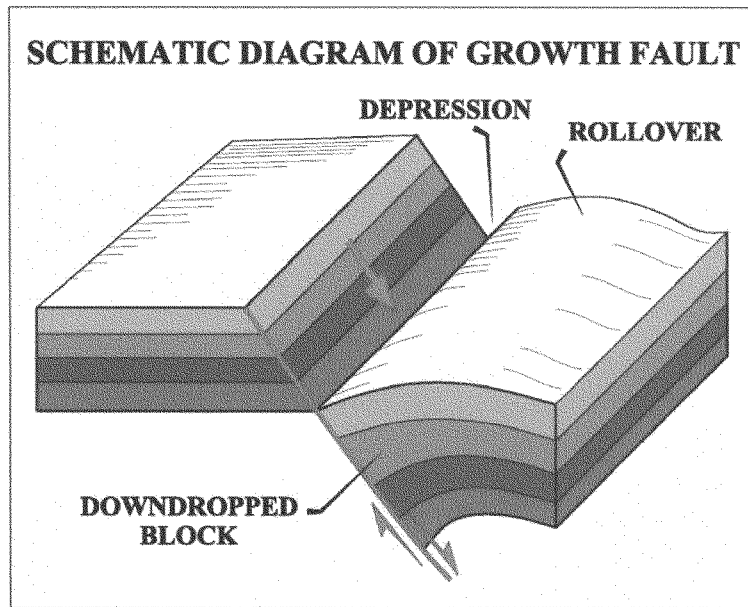


Figure 4. Growth faults are breaks in beds of rock or sediment where slippage has occurred. Individual beds are characteristically thicker on the downdropped block indicating movement of the fault during deposition of the beds. As the downdropped block slides along the fault plane, it tends to rotate, resulting in a depression aligned along the fault trace and an uplift or rollover structure forms in a down dip direction. Movement along the faults may be at intermittent intervals and, or slow and imperceptible, but continues over long periods of time.

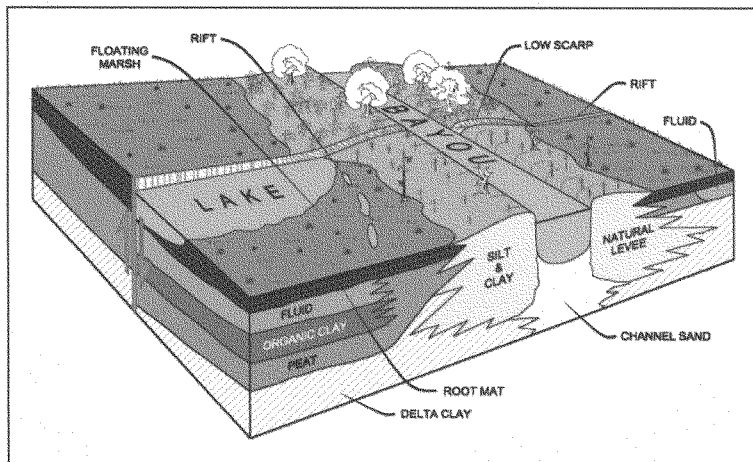


Figure 5. Diagram showing effects of growth fault movement on different landforms and near-surface deposits in the deltaic plain of southeastern Louisiana. The effects on flood protection levees and floodwalls are similar to those on the natural levee ridges bounding the bayou.

Fault-driven submergence is responsible for more than half of the total land loss that has occurred in south Louisiana since the 1930's (Figure 6). Fault movement affects surface landforms and infrastructure including ridges, barrier islands, wetlands, flood protection levees, highways, and coastal communities. Depressions along faults and fractures, and tilting of fault-bound blocks also strongly influence the alignment and channel-meander configuration of the Mississippi River and its distributaries in the deltaic plain. Barrier island breakup, as well as river bank failure have been linked to fault movement. A cause and effect relationship has been established between modern fault movement and the catastrophic land submergence and loss that has occurred in coastal Louisiana during the last 50 years (Gagliano et al. 2003a, 2003b.)

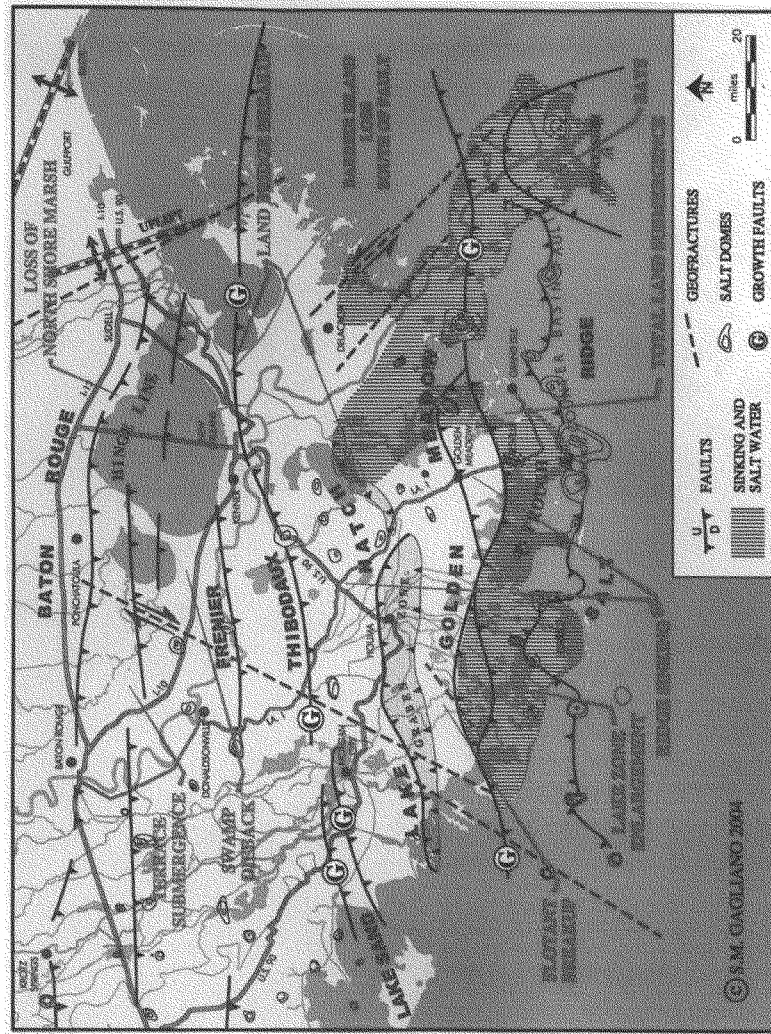


Figure 6. Map showing areas of land submergence and other environmental deterioration related to fault movement in southeastern Louisiana.

The GNO area lies along the upper margin of the Eastern Tectonic Province of the Gulf Coast Salt Dome Basin (Figure 7). Movement is occurring on deep-seated faults that are part of the tectonic framework of this province. The Eastern Province is in effect a giant gravity slump block, the toe of which lies in the deep waters of the Gulf of Mexico and the crown fault underlies the GNO area (Figures 7 and 8). The faults within the tectonic framework are moving in response to this massive continental margin slumping, which is driven primarily by basin sinking, sediment loading, gravity, and movement of underlying salt deposits. Onshore components of the linked framework are expanding or pulling apart and thus creating surface depressions and block tilting, while offshore components are contracting into folds and thrust faults that are piling up at the base of the continental slope.

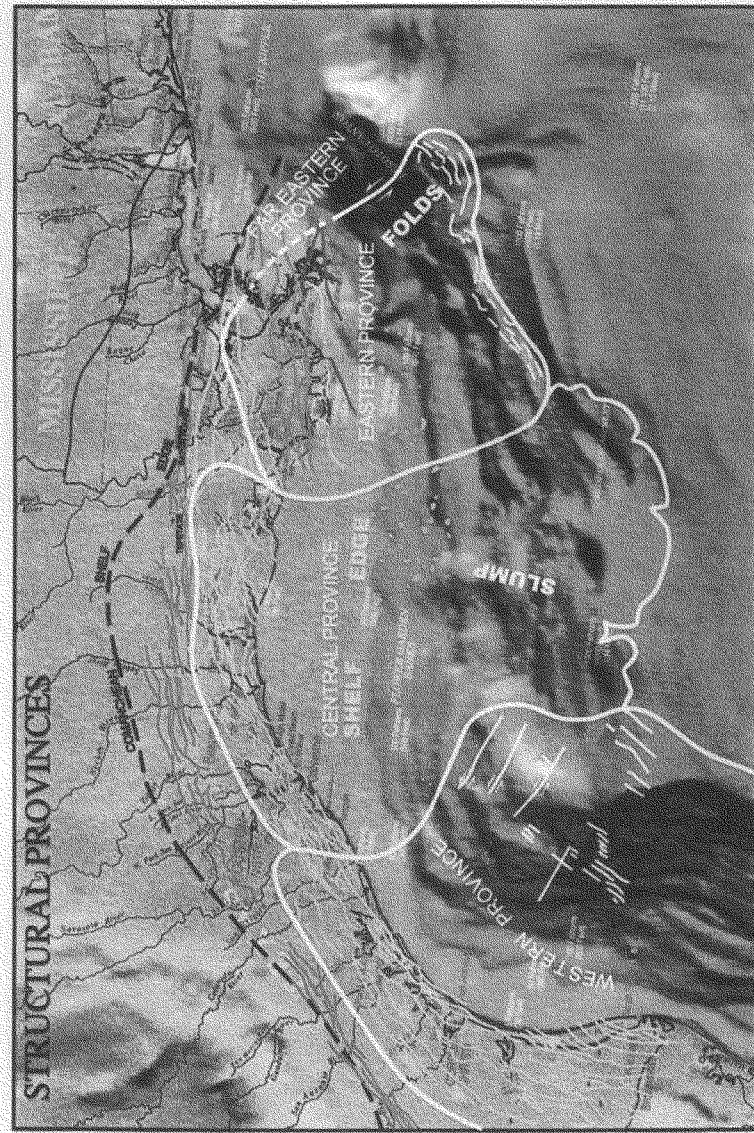


Figure 7. The onshore faults and fractures are parts of linked regional tectonic systems that extend into the deep Gulf. The crown faults of the Eastern Province underlie the Greater New Orleans area (base map with permission of Port Publishing Co., Houston, Texas, structural provinces modified from F. J. Peele et al. 1995, faults after GCAGS).

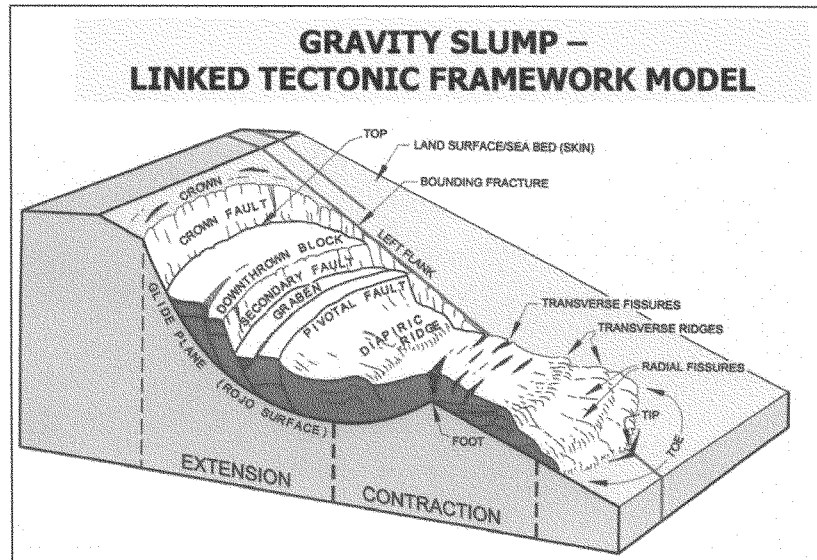


Figure 8. Gravity slump model showing relationships of structural elements of the Eastern Tectonic Province, as shown in Figure 7. The GNO area lies above the crown fault of the slump system.

The crown faults at the head of the Eastern Province slump underlie the GNO area and have controlled the trends of ancient Mississippi River distributaries. For example, the position of the Metairie-Gentilly ridge, which is made up of a pair of natural levee ridges that mark a 3,000 year old course of a now extinct Mississippi River distributary is controlled by the crown faults. In addition, the trends of shallow buried barrier island sands, which underlie parts of the Lakeview, Little Woods and the New Orleans East areas are also controlled by the crown faults. The breaches that occurred on levees along the 17th Street and London Avenue Canals are at places where the levees were built across the crown faults and may be the cause of the floodwall breaches. Secondary processes, which may result in localized subsidence include sediment compaction, soil de-watering and fluid withdrawal (ground water, hydrocarbons and produced water).

Figure 9 shows the depth to the weathered surface that marks the top of the Pleistocene formation. The weathered surface is important from the geotechnical standpoint as this is a load-bearing horizon and above it lies poorly consolidated Holocene deposits. Depth to the top of the Pleistocene is less than 100 feet throughout the GNO region. Figure 9 also shows geofractures, subsurface faults, and salt domes. The top of the Pleistocene is displaced by many of these deep-seated structures. In most geotechnical studies, the top of the Pleistocene is considered to be a stable foundation bearing horizon.

The Baton Rouge Fault Zone is a major regional feature that marks the northern boundary of the Gulf Coast Salt Dome Basin. This is a hinge line fault. That is, the land surface north of the fault is rising, and south of the fault the land surface is sinking. This fault zone is marked by a pronounced topographic escarpment that separates Lakes Pontchartrain and Maurepas and their surrounding wetlands from the pine-covered terrace lands of the "North Shore." Segments of this fault zone are known to be active. Highway pavement cracks must be frequently repaired and railroad tracks must be frequently adjusted where they cross this fault zone.

The Lake Sand-Thibodaux Fault, one of a series of Oligocene growth faults that underlie Lake Pontchartrain and the GNO area, is the crown fault of the Eastern Province. Displacement of the top of the Pleistocene Formation has been identified from correlations of boring logs and on sub-bottom acoustical profiles across several of the Oligocene faults under Lake Pontchartrain. Highway and railroad bridges across the lake are also cracked, offset and displaced where they cross these faults. These offsets have been documented in the geological literature (Lopez et al. 1997). It should be noted that salt domes, which are associated with many of the faults

of the region, are absent or rare in the GNO area geofractures constitute another important category of structural features that have surface expression and may affect foundation conditions. An extension of the northwest-southeastern trending Terre aux Boeufs Geofracture cuts through the GNO area (see Figure 9). This feature segments the blocks between some of the regional growth faults.

Figure 9. Map showing depth to the weathered surface of the Pleistocene, geofractures, subsurface faults, and salt domes (modified from Gagliano et al. 2003a, Pleistocene depth data from L.D. Britsch 2001).

Many of the east-west trending growth faults terminate at their intersection with this geofracture. The Lake Borgne Geofracture (Fault) Zone strikes northeast-southwest and has played an important role in determining geometry of river courses in the area as well as the formation of lakes and bays. Fault segments in this zone may have contributed to the floodwall breach along the Inner Harbor Navigation Canal (IHNC, also known as the Industrial Canal).

Although some regional faults have been active for millions of years, contrary to common belief, not all movement has occurred during the dim geological past. Some faults have moved during, prehistoric Native American times (the last 12,000 years), historic times (the last 300 years) and modern decades (the last 50 years). Surface effects of fault movement have been reported from numerous locales across south Louisiana (Lopez et al. 1997, Gagliano 1999, Keucher et al. 2001, Morton et al. 2002, Gagliano et al. 2003a Gagliano 2005, and others). Figure 10 shows dates of surface movement of faults in southeastern Louisiana, as determined from comparative studies of aerial images and maps. For example, comparison of aerial photographs taken in 1976 and 1982 show surface displacement along a fault segment at Bayou Long (Gagliano et al. 2003a). Lake Lery is a fault depression that is depicted on the earliest historic maps of the region and is shown in Figure 10 as pre-1803 surface fault movement. Modern fault events occur along fault segments from 1 to 5 miles in length with vertical displacement of a few inches to 5 feet or more. Fault events result in the formation of lakes and bays, submergence and breakup of marsh, submergence of natural levee ridges, and submergence and breakup of barrier islands.

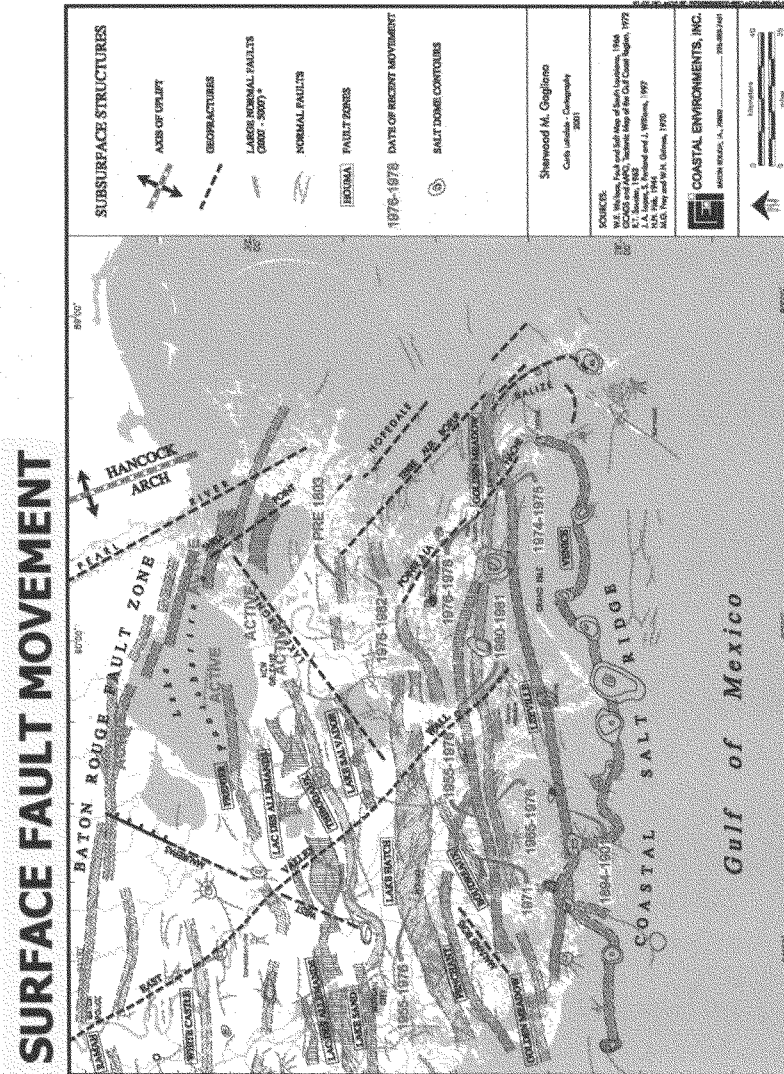
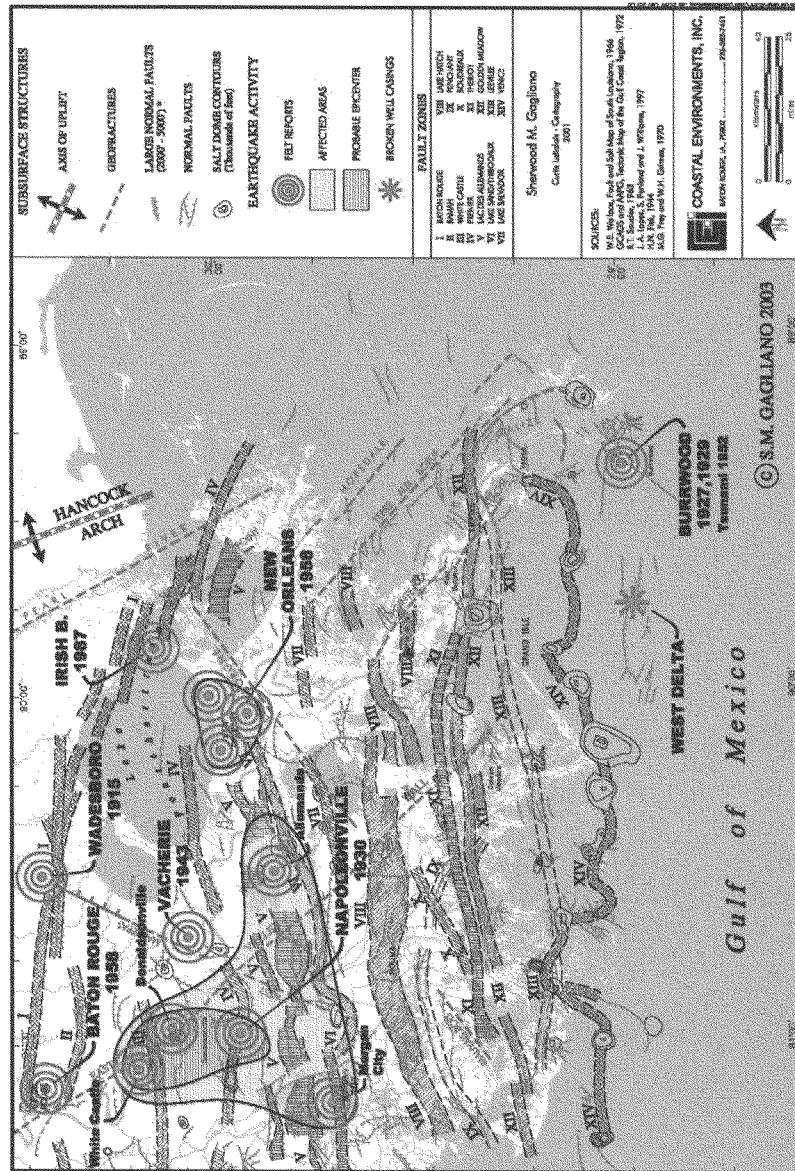


Figure 10. Map showing dates of surface fault movement in reference to known subsurface faults.

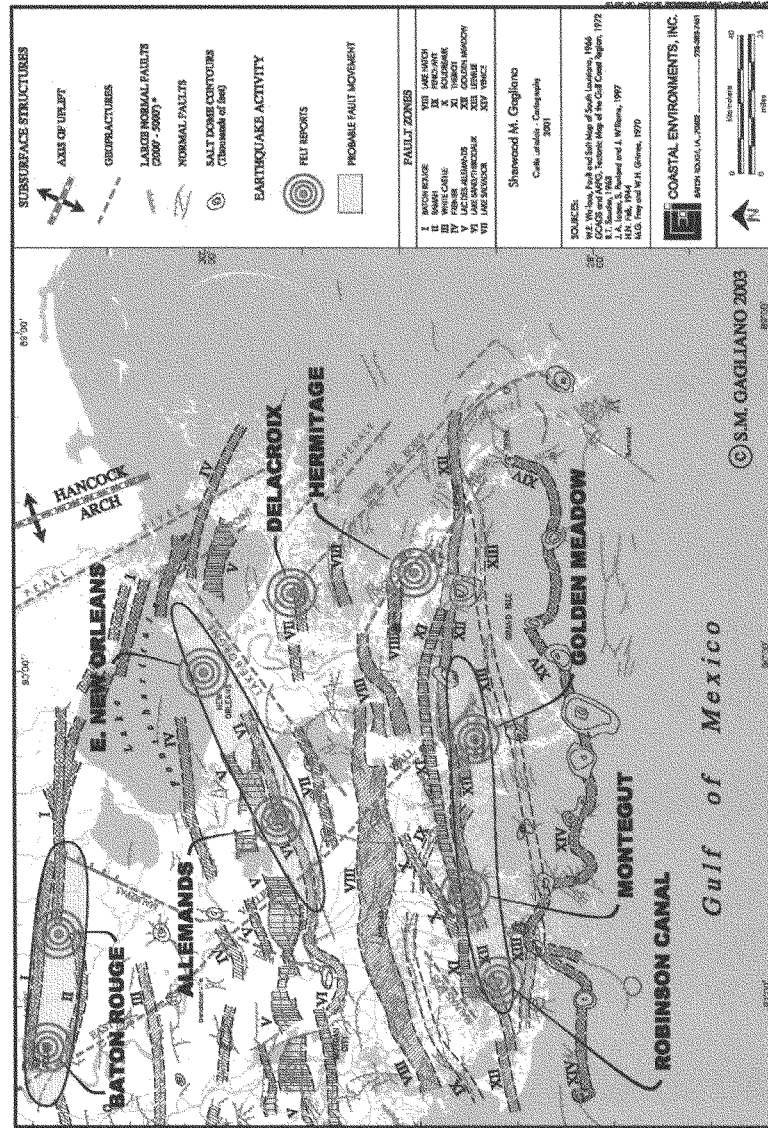
FAULT MOVEMENT AND EARTHQUAKES

Earthquake occurrences indicate locations of active faults. Two categories of earthquakes have been reported in south Louisiana. The first is caused by random slippage on subsurface faults. Figure 11 shows locations where this type of earthquake has occurred. Those within and near the GNO region are aligned along the Lake Sand-Thibodaux Fault Zone. On November 6, 1958 an Intensity IV earthquake occurred within a 5- to 7-mile radius of downtown New Orleans. The area where effects of the earthquake were felt extended from Lake Pontchartrain on the north to Gretna on the south and from Harahan on the west to Arabi on the east. The earthquake was recorded on the Loyola University seismograph located in New Orleans as a 15 second vibration. The earthquake caused windows to shake and doors to rattle (Brasseaux and Lock 1992:319, Stevenson and McCulloh 2001:6)



F Figure 11. Location of reported felt effects of historic earthquakes in southeastern Louisiana and correlation with known subsurface faults.

The second type of earthquake occurs when shock waves from distant earthquakes trigger slippage along local faults, which in turn may cause a secondary earthquake (Gagliano 2005) (Figure 12). An event particularly relevant to the Hurricane Katrina IHNC floodwall breach occurred on March 27, 1964 at 10:00 PM when “. . .swells were reported in the Industrial Canal [IHNC] NEAR new Orleans. . .” UPI, New Orleans, 1964. “‘It caused our docks and vessels moored in the yards to go crazy-like, bobbing up and down, moving sideways, back and forth.’ Said Leon Poche 47, superintendent of Avondale Shipyards.” AP, New Orleans 1964a. “‘The water rose about 6 feet above normal all at once,’ said O.C. Boxton, night watchman at New Orleans Industrial Canal. ‘It was one of the wildest scenes that I’ve seen in a long time,’ he said. The water was rolling, barges began to move in and out and the lines (holding the barges) began to turn and break.” AP, New Orleans, 1964b. “One marine company at New Orleans said the waves in the Intracoastal Canal were ‘at least 4 or 5 feet.’ Several boats were torn loose, including a line holding an 83-foot Coast Guard vessel.” AP, New Orleans, 1964.



F Figure 12. Locations of reported effects of apparent secondary earthquakes in southeastern Louisiana triggered by shock waves of the M 9.2 Prince William Sound Earthquake of March 27, 1964.

This Industrial Canal event was apparently triggered by arrival of shallow shock waves from the Alaskan Earthquake of Prince William Sound of the same date and 12 minutes earlier. It took the shallow seismic waves approximately 12 minutes to travel 3200 miles from the epicenter of the Alaskan earthquake to south Louisiana. The intensive water disturbances indicate the presence of an active fault. During Hurricane Katrina in 2005, the two breaches that occurred in the floodwall along the east bank of the Industrial Canal were in the same location as the 1965 earthquake induced water disturbances. It was these breaches that caused extensive flooding in the Lower 9th Ward of New Orleans and adjacent areas of Arabi and Chalmette in St. Bernard Parish.

MEASURING MOVEMENT

Rates, magnitude and frequency of movement have been determined for some faults. Several data sets have been used to measure vertical movement of land surfaces in south Louisiana, including tide gauge records, differential elevations of resurveyed topographic bench marks, movement of historic and archaeological features and structures, land loss, habitat change and radiometric dating of buried deposits. These measurements have been related to known faults. Tide gauge records indicate that the Little Woods area along the Lake Pontchartrain shore in New Orleans, in the general vicinity of the London Avenue Canal Breach, has one of the highest rates of subsidence in the state. Records from a tide gauge at Little Woods show a total relative sea level rise (subsidence plus eustatic rise) of 1.84 feet for the period between 1940 and 1976, for a rate of 0.51 feet per year. Further, the record is distinctly "stepped," suggesting episodic fault movement.

Resurveyed bench marks at the NASA-Michoud facility, located near the IHNC breach, likewise show exceptionally high subsidence rates. The NASA-Michoud measurements also indicate accelerated movement during recent decades.

Recently, the National Geodetic Survey (NGS) in conjunction with the Spatial Data Center at Louisiana State University (LSU) has re-evaluated vertical change data from benchmarks. Dr. Roy Dokka, director of the LSU team, reports that "...loss of elevation ranges from 0.3 to 0.13 feet per year across south Louisiana. . ." (NOAA Magazine 2003). The NGS-LSU findings are generally consistent with those presented herein.

TYPES OF FAULT IMPACTS

There are three categories of fault impacts. The first is subsidence and tilting of the surface near and between faults. This effect is most pronounced on the downthrown block in the immediate vicinity of the fault. On a larger scale, entire fault-bound blocks tilt and subside. Large areas become inundated creating lakes and bays within short time intervals. As stated previously, fault induced land submergence is the primary cause of land loss in southeastern Louisiana (Figure 6).

The second category of impact relates to foundation instability along and within the immediate vicinity of the fault plane or zone. Movement may be instantaneous or slow and imperceptible. Even when slow and imperceptible, fluids and gas may migrate toward the surface along the fault plane (Keucher et al. 2001, Gagliano et al. 2003a). Some fault planes are pencil line thin with surfaces that exhibit slickensides (smoothed and striated surfaces that result from friction along fault planes) and/or clay and mineral films. Other faults exhibit multiple, parallel planes. Another type is characterized by brecciated zones, where clay particles are broken into pellets as a result of movement along the fault zone. Sand and silt dikes that may be several feet wide may also mark fault planes. In all cases, the fault plane or fault plane zone is a deep crack in the earth's surface. Foundation conditions across the crack are poor and if a levee or floodwall is built across the fault, the fault plane may become a conduit for piping or seepage under the levee base or under the bottom of interlocking steel sheet piles. Since the faults are deep-seated, the depth of the cracks may be greater than the bottom of the longest sheet piles.

The third category of instability relates to minor earthquakes and related phenomena such as liquefaction. As previously discussed, earthquakes may result from sudden release of pent-up stress or may be triggered by shock waves from remote earthquakes. When accompanied by earthquakes, fault movement effects may include liquefaction, breakup of floating marsh mats and other damage to landforms and human-made structures (Figure 5). Liquefaction occurs when earthquake vibrations cause buried sand deposits to become more compact and in the process expel pore water. The expelled water may form "sand fountains" in which sand-charged water shoots up above the surface through fault crevices.

Hurricane waves are known to cause slumping along the unstable delta front area offshore from the active outlets of the Mississippi River. It is conceivable, though

it has not been proven, that the weight of the elevated water column in the canals combined with the pounding of wind-generated waves during Hurricane Katrina could have caused release of pent-up stress on active faults.

RELATIONSHIP BETWEEN FAULT AND FLOODWALL BREACHES IN THE GNO AREA

Available data suggests that the breaches along the 17th Street Canal, the London Avenue Canal (2 breaches) and the IHNC (2 breaches) were at least partially caused by underlying faults. The 17th Street Canal and London Avenue breaches appear to be on the same fault zone. This fault controlled the location of a series of southwest-northeast trending barrier islands that formed through what is presently the Metairie-Lakeview area about 5,000 years ago. It was sand from one of these barrier islands that was expelled to the surface at the breach on the London Avenue Canal during Hurricane Katrina.

Surface inspection of the larger IHNC breach site revealed evidence of a possible fault (Figure 13). The site was inspected after a long drought. Aligned desiccation cracks and water seeps called attention to what appears to be a silt dike. As shown in the photographs in Figure 13, the feature runs under the emergency levee that was constructed to close the breach and apparently under the base of the failed floodwall.

Could this silt dike have formed as a result of liquefaction during the 1964 earthquake event? While the evidence is not conclusive, it demands further investigation.

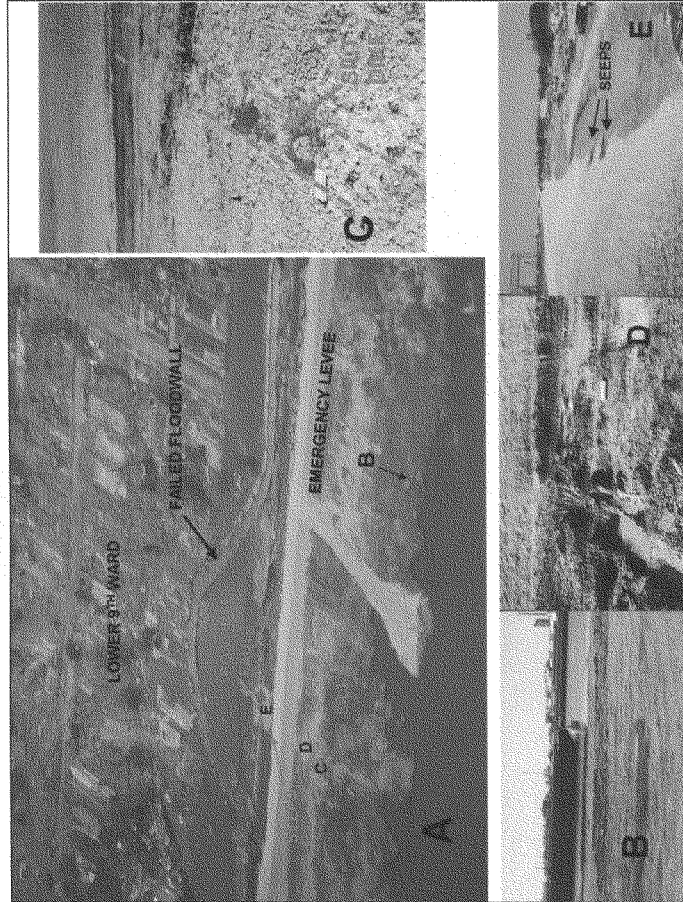


Figure 13. Floodwall breach on the east side of the Inner Harbor Navigation Canal in New Orleans. A. View looking southeast across area of floodwall failure. Uprooted steel sheet piles capped with concrete are clearly visible. B. View of canal looking west. Water level in the canal is approximately 1 to 1.5 feet below batture land level. Except where disturbed by vehicle movement, the batture in this area is grass-covered and not deeply scoured by water flow. C. Water seepage through possible silt dike. D. Seepage through possible silt dike at base of emergency levee, canal side. E. Seepage at base of emergency levee, east side. These seepage patches align with the possible silt dike on the west side of the levee.

Figure 14 is a schematic representation of a canal with floodwalls constructed across a fault. As shown, the stability of the levees and floodwalls could be affected by the poor foundation conditions within the fault plane zone, by piping of water under the levees and sheet pilings along the fault plane or within the fault plane zone, and by sagging of the levee crown.

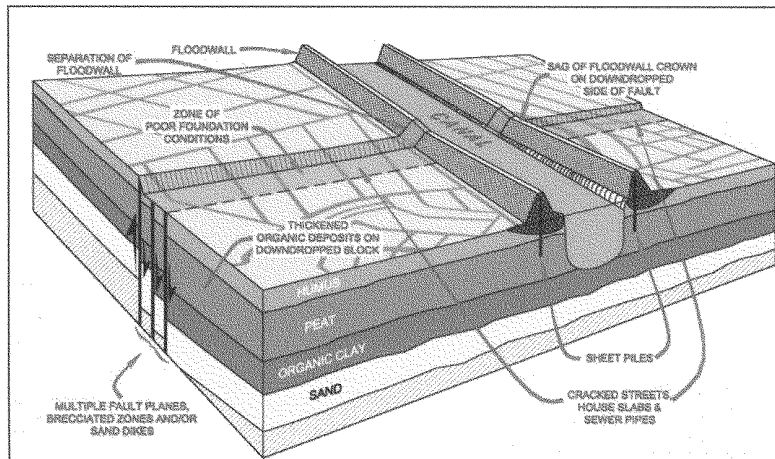


Figure 14. Diagram showing possible effects of a fault on levees and floodwalls built across the fault plane.

Breaches along the MRGO hurricane protection levee southwest of Lake Borgne (Figure 2) at the Bayou Bienvenu and Bayou Dupre floodgates are most likely the result of levee overtopping and return surge flow.

FAULT HAZARDS ALONG EXISTING AND PROPOSED LEVEE ALIGNMENTS

As shown in Figure 1, proposed levee alignments in southeastern Louisiana cross major known faults at a number of locations. Breaches in the flood levees along the Mississippi River in Plaquemines Parish below New Orleans may have been caused by underlying faults. The levees are constructed across several major fault zones including the large and active Lake Hatch and Golden Meadow fault zones. At some of these fault crossings, steel sheet pilings had been installed to reinforce the earth levees prior to Hurricane Katrina because of chronic foundation problems.

Breaches in levees have also occurred during two hurricanes where levees were constructed across known faults in the vicinity of Montegut, south of Houma, Louisiana.

As shown in the photograph in Figure 15, a flood levee was constructed across the Montegut Fault. Surface expression of this fault is distinguished by a marsh-water break.

The surface expression of this fault appeared between 1972 and 1976. Field studies at this location showed 3.3 feet of change in elevation from the marsh surface to the pond bottom and a comparable amount of displacement of near-surface beds as determined from borings.

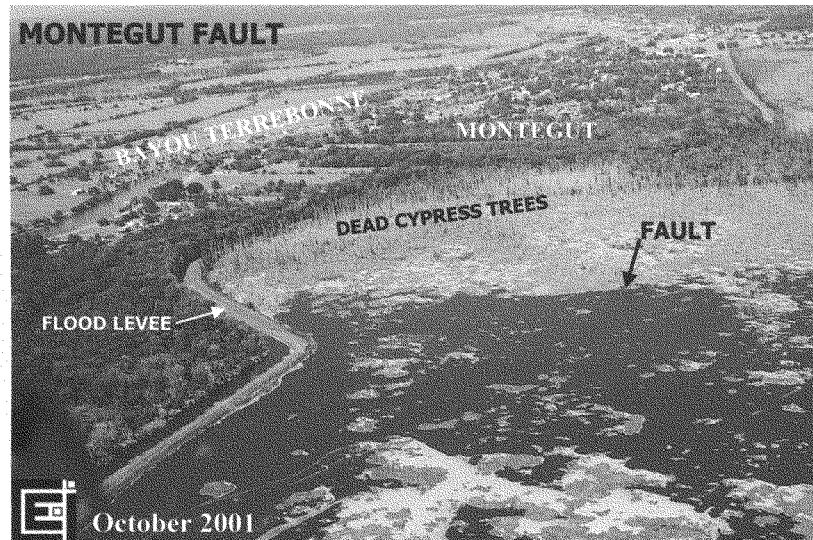


Figure 15. Flood levee constructed across an active fault at Montegut, Louisiana. The levee failed at this location during Hurricanes Isadore and Katrina. The view is looking north across a large pond and broken marsh on the down-dropped block of the fault. Note the dead cypress trees on the up-thrown block. The flood protection/drainage levee is located along the back-slope of the Bayou Terrebonne natural levee ridge. The Montegut community is located on the natural levee. Photography S.M. Gagliano, October 17, 2001.

SUMMARY AND CONCLUSIONS

Evidence from a number of different data sets indicates that faults in the GNO area and throughout southeastern Louisiana have been active during recent decades. Levees and floodwalls have been built across these active faults. Strikes of known subsurface faults are parallel to lines projected between levee breaches along the London Avenue and 17th Street Canals. Converging lines of evidence suggest that floodwall breaches along the IHNC are fault-related. There are numerous other problem areas where existing and proposed levee alignments cross known, active faults.

Hurricane protection and wetland restoration have been regarded as a battle against the erosive forces of the sea, a horizontal engagement. Findings of the tectonic studies indicate that the dominant processes are geological and the changes are vertical, thus requiring a fundamental shift in battle strategy.

While faults represent serious geological hazards in southeastern Louisiana, they do not present an insurmountable obstacle in our quest for adequate storm and flood protection. However, fault hazards must be taken into consideration in planning and design of protection levees and all other infrastructure (including flood-gates), as well as in the coastal restoration program.

The issue that fault driven subsidence is the major cause of land loss and coastal deterioration in south Louisiana has been on the table for more than 5 years and has largely been circumvented by the coastal restoration community and most public officials. This is partially due to the fact that fault processes and effects have only recently been understood. This is new science and it takes time to be absorbed. However the main reason is the difficulty of informing citizens and businesses that their property is on the wrong side of a fault, and therefore, may be impossible to protect and maintain. Fault movement and related land subsidence are natural processes and there is no institutional or corporate villain. We are in denial. (Figure 16).

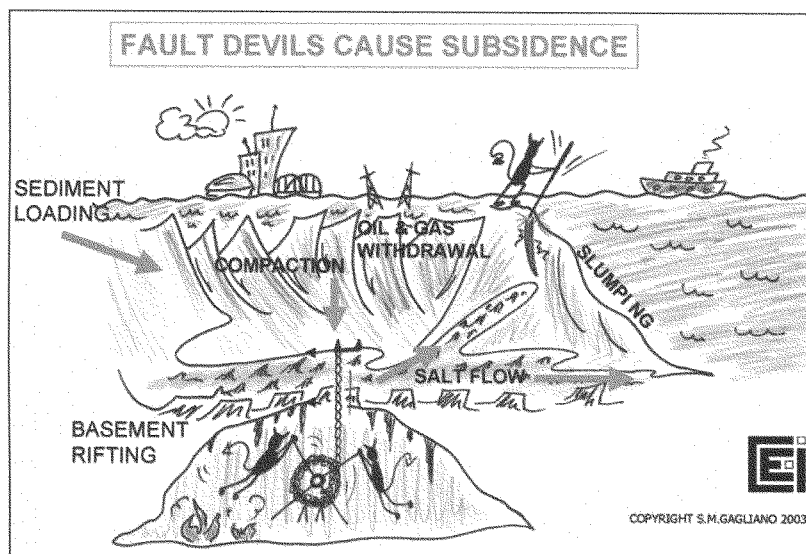


Figure 16. Fault induced subsidence is not a politically correct theory. Most people in Louisiana, including most public officials, do not understand, or will not accept that the southern edge of the state is being submerged as a result of fault movement that has accelerated during the past 50 years.

If our efforts to protect the Louisiana coast are to succeed, we must test each hypothesis and not arbitrarily reject those that predict outcomes that are difficult to resolve or hard for the public to accept. We can't cure the disease if we don't know the cause. This testimony deals with a controversial and sensitive topic and is advanced in the hope of stimulating solutions and not to stifle a program of protection and restoration of coastal Louisiana.

REFERENCES

- AP, New Orleans. 1964a. State's Twitch of Earth Said 'Weird.' Lake Charles American Press, March 29, 1964. Lake Charles, LA.
- AP, New Orleans. 1964b. Tremors Churn 6-Foot Waves in Louisiana. March 27, 1964. Beaumont Enterprise, March 28, 1964. Beaumont, TX.
- AP, Houston 1964. Resident Warned. Beaumont Enterprise, March 28, 1964. Beaumont, TX.
- Brasseaux, C. A. and B. E. Lock. 1992. The Opelousas Earthquakes of 1823 and 1870. Louisiana History, Louisiana Historical Association. V. 134, No. 3, pp. 317-324.
- Britsch, L. D. 2001. Geologist, U.S. Corps of Engineers New Orleans District. Personal communication with Sherwood Gagliano in 2001.
- Gagliano, S. M. 1999. Faulting, Subsidence and Land Loss in Coastal Louisiana. Pp. 21-72 In Louisiana Coastal Wetlands Conservation and Restoration Task Force and Wetlands Conservation and Restoration Authority, Coast 2050: Toward a Sustainable Coastal Louisiana, the Appendices, Appendix B-Technical Methods. Louisiana Department of Natural Resources, Baton Rouge, LA.
- Gagliano, S. M. 2005. Effects of Earthquakes, Fault Movements, and Subsidence on the South Louisiana Landscape. In the Louisiana Civil Engineer Journal of the Louisiana Section of The American Society of Civil Engineers. V. 13, No. 2, pp. 5-7, 19-22.
- Gagliano, S. M., E. B. Kemp, K. M. Wicker, and K. S. Wiltenmuth. 2003a. Active Geological Faults and Land Change in Southeastern Louisiana. Prepared for U.S. Army Corps of Engineers, New Orleans District, Contract No. DACW 29-00-C-0034.
- Gagliano, S. M., E. B. Kemp, K. M. Wicker, and K. S. Wiltenmuth. 2003b. NeoTectonic Framework of Southeastern Louisiana and Applications to Coastal Restoration. Transactions of the Gulf Coast Association of Geological Societies; v 53: 262-276.

Kuecher, G. J., H. H. Roberts, M. D. Thompson, and I. Matthews. 2001. Evidence of Active Growth Faulting in the Terrebonne Delta Plain, South Louisiana: Implications for Wetland Loss and the Vertical Migration of Petroleum. *Environmental Geosciences*; 8:2:77–94.

Lopez, J. A., S. Penland and J. Williams. 1997. Confirmation of Active Geologic Faults in Lake Pontchartrain in Southeast Louisiana. *Transactions of the Gulf Coast Association of Geological Societies*, 47th Annual Convention; 47:299–303.

Morton, R. A., N. A. Purcell, and R. Peterson. 2001. Field Evidence of Subsidence and Faulting Induced by Hydrocarbon Production in Southeast Texas. *Transactions of the Gulf Coast Association of Geological Societies* 51: 239248.

NOAA Magazine. 2003. NOAA–LSU Study: Portions of Gulf Coast Sinking at Significant Rate. April 16, 2003. <http://www.noaanews.noaa.gov/stories/s1128.htm>.

Peel, F.J., Travis, C. J. H. and Hossack, J.R. 1995. Genetic Structural Provinces and Salt Tectonics of the Cenozoic Offshore U.S. Gulf of Mexico: A Preliminary Analysis. Pp. 153–175 In Jackson, M.P. A, D.G. Roberts, and S. Snelson, (Eds.) *Salt Tectonics, A Global Perspective*, American Association of Petroleum Geologists Memoir 65.

UPI, New Orleans. 1964. South Louisiana Shakes Like Bowl of Jelly. *Opelousas Daily World*, March 29, 1964. Opelousas, LA.

RESPONSES BY SHERWOOD M. GAGLIANO TO ADDITIONAL QUESTIONS FROM
SENATOR JEFFORDS

Question 1. I have read some of your statements in the press regarding the need to consider relocating people out of some low-lying areas of the city. A theme we have heard throughout our hearings on Katrina is that local redevelopment plans must drive federal investment.

Response. It is becoming clear that a significant part of the total population of the Greater New Orleans area seriously affected by Hurricanes Katrina and Rita have already been displaced and the total population will not be as large as it was before the storms. Further, it is likely that the population density will be most significantly reduced in the areas of lowest elevation that were hardest hit. Some of the lowest, hardest hit areas should not be rebuilt. The property owners there should be compensated for their losses and provided with re-location assistance. The plan proposed by Representative Richard Baker addresses the compensation part of the problem.

From the flood protection standpoint, these very low places should become water retention areas in a revised pumping and drainage plan. They would absorb part of the runoff during intense rainfall events and thus provide lead-time for the pumps to remove water from the urban drainage districts.

An alternative approach would be to fill and build up these low areas with silt and sand pumped in from the Mississippi River with hydrologic dredges. After allowing for settlement, the raised areas could be re-developed. This would provide a long-term solution to the subsidence problem.

Question 2. The Mayor and the Governor both have processes underway can you give me your opinion on how those processes are going and what we need to know about their progress so far?

Response. Too many commissions and too many outside experts are only adding confusion to the process of planning and re-building.

RESPONSES BY SHERWOOD M. GAGLIANO TO ADDITIONAL QUESTIONS FROM
SENATOR VITTER

Question 1. Most people do not associate faults with Louisiana or, at least geological faults. Otherwise, we are well known as being perfect. According to the information you provided to the committee, faults crisscross the southern part of the state. Are you suggesting that we avoid faults in the construction of our protection systems? Is this possible?

Response. Faults are fixed, permanent features of the setting of South Louisiana and we know where most of them are. They present two types of hazards: (1) failure of structures built above or across the fault plane or zone, and (2) subsidence and tilting of the large land blocks between major faults. We can mitigate the first type of hazard by avoidance to the greatest extent possible, and by good engineering design where avoidance is not feasible. Subsidence and tilting of large blocks presents a greater challenge. Unfortunately, there are large blocks of land in the extreme southern parts of Louisiana that lie on the down-dropped sides of regional faults,

and we know where these areas are, that will become increasingly submerged. If we refuse to recognize this process, we will waste huge numbers of tax dollars and huge amount of human effort in a battle against nature that cannot be won.

We have discovered the cause of the "disease" that is changing coastal Louisiana as we have known it during most of the historic period. We must now apply this knowledge in re-shaping the coast so that we can provide a sustainable infrastructure for essential coastal communities and services and, at the same time, develop a program for managing natural delta lobes and estuaries wrapped around the protected areas of human activity. Such a plan for true multiple use and sustainability is achievable, but it does not presently exist. Louisiana will always have a coastal zone, but we must accept the fact that it dynamic and subject to change.

Question 2. What design features should be incorporated into our levees and floodwalls to address the movement of the faults?

Response. First, we must identify those places where existing and proposed levee alignments are along, or across faults. A risk analysis, based on sound geological and geotechnical data should be conducted on levee alignments and specific locations where fault hazards are found. In some instances, existing and proposed levee alignments and floodgate locations should be changed. Clearly, it is easier to do this on proposed projects than existing ones, yet there is resistance to making these changes when some planning and engineering work has already been done. Floodgates and other water control structures should never be built above fault or on the immediate down-dropped side of faults. There are a number of locations in south Louisiana where existing and proposed water control structures are located above fault plane zones or on the down-dropped block of faults in close proximity to fault plane zones.

Second, where levees or floodwalls cross faults, sheet piling is an effective tool provided that it is significantly deeper than the water-body on the outside of the structure. If foundation conditions are particularly poor along the fault plane zone, a second row of sheet piles should be considered.

Expansion joints should be provided where rigid floodwalls cross fault plane zones.

Levee and floodwall locations across faults should be continuously monitored. While movement on most faults in south Louisiana is slow and imperceptible, stresses build up and may be released spontaneously or as a result of shock waves. When such releases occur, there may be a rapid vertical movement of several feet and possible minor tremors.

Conventional geotechnical engineering borings and laboratory testing do not identify faults. Conventional geotechnical data must be analyzed and interpreted by a trained geologist. Our understanding of liquefaction processes is poor. This process needs further research.

Question 3. Is it possible to retrofit our existing levees and floodwalls to address this issue?

Response. In most cases existing levees and floodwalls can be retrofitted to prevent failures related to slow and imperceptible fault movement. There may be one or more floodgates that need to be re-located.

Question 4. What role did geologic faults play in the floodwall failures in New Orleans?

Response. SMG Response A lengthy answer to this is provided in my written testimony. There is evidence that the floodwalls that failed on the 17th Street Canal, the London Avenue Canal and the Inner Harbor Navigation Canal were built across active, deep-seated geological faults. Poor foundation conditions within the fault plane zone and piping of water along the fault plane zone under the levees and sheet pilings could have caused the failure. Also, slow and imperceptible movement may have caused the crests to sag, and separations to occur in the sheet pilings

Question 5. Could you explain the relationship between faults and subsidence in Louisiana?

Response. The primary cause of subsidence in south Louisiana are geological processes of basin down-warping, salt movement, and continental margin gravity slumping, which occur on a massive regional scale and have been continuous for several hundred million years. Additional processes contributing to local subsidence include sediment compaction and fluid withdrawal. Faults are the breaks in the underlying rocks and near surface sediments along which adjustments to subsidence occur. For all practical purposes they are permanent features of our land.

The subsidence that causes land submergence and loss is mainly the result of downward movement and tilting of blocks of land lying between faults (fault bound

blocks). Usually, the subsidence is most pronounced on the down-dropped block in a zone along the fault plane.

STATEMENT OF LARRY ROTH, P.E., DEPUTY EXECUTIVE DIRECTOR, AMERICAN SOCIETY OF CIVIL ENGINEERS

Good morning. My name is Larry Roth. I am the deputy executive director of the American Society of Civil Engineers (ASCE).¹ I am pleased to appear before you today to testify on behalf of ASCE to discuss the preliminary findings on the failure of the Gulf Coast levees during Hurricane Katrina in August 2005 and the degree to which levee repairs are incorporating those findings. I am accompanied today by John Headland, P.E., M.ASCE, Design Manager, Moffatt & Nichol Engineers, and a member of the ASCE Levee Assessment Team in New Orleans.

I am a licensed Professional Engineer and a licensed Geotechnical Engineer in the state of California. Before joining the ASCE staff, I had 30 years' experience in water resources issues such as dams, levees, and canals.

I. ASCE NEW ORLEANS LEVEE ASSESSMENT TEAM

After the storm, ASCE assembled several teams of experts to examine the failures of the New Orleans levee as well as to examine the shoreline damage along the Alabama and Mississippi coastline. Our New Orleans team of coastal engineers was joined by another ASCE team of geotechnical engineers and one from the University of California, Berkeley. These teams were joined there by a team from the U.S. Army Corps of Engineers' Engineer Research and Development Center, which provided considerable insight and logistical support.

The purpose of this joint site visit was to gather information about the failure of the levees, including data that would be lost during the process of levee repair and the passage of time, such as evidence of high water lines and wave overtopping, and evidence of any foundation movement or failure.

One of the goals of the assessment team was to gather data in an attempt to determine why certain sections of the levee system failed and why others did not. These determinations will help to answer the question of whether the failures were caused by localized conditions or whether surviving sections of the system may be only marginally better prepared to withstand the type of loads that were generated by this event.

The team assembled consisted of professional engineers from ASCE with a range of geotechnical engineering expertise in the study, safety, and inspection of dams and levees. While in New Orleans and the surrounding areas between September 29 and October 15, ASCE examined levee failures as well as distressed and intact portions of the levee system.

Defense Secretary Donald H. Rumsfeld announced in October the creation of an independent panel of national experts under the direction of the National Academies of Science to evaluate the performance of hurricane protection systems in New Orleans and the surrounding areas. Under the National Academies, the National Research Council will assemble a multi-disciplinary, independent panel of acknowledged national and international experts from the public and private sectors and academia. This panel will perform a high-level review and issue a final set of findings based primarily on the data gathered by another organization, the Interagency Performance Evaluation Task Force (IPET).

The IPET will include a broad interagency participation, private sector and academic expertise. The IPET is to obtain the facts by collecting, analyzing, testing, and modeling data and information on the performance of the New Orleans hurricane protection system during Hurricane Katrina.

Rumsfeld also authorized ASCE to convene an external review panel to conduct continuing expert peer review of the work performed by the IPET. The ASCE external review panel, of which I am the chief of staff, will also report findings directly to the National Research Council.

¹ ASCE, founded in 1852, is the country's oldest national civil engineering organization. It represents more than 139,000 civil engineers in private practice, government, industry, and academia who are dedicated to the advancement of the science and profession of civil engineering. ASCE carried out Building Performance Assessments of the World Trade Center, the Pentagon and the Murrah Federal Building, and technical assessments following earthquakes, hurricanes, and other natural disasters. The New Orleans levee technical group includes representatives appointed by the ASCE Geo-Institute and ASCE Coasts, Oceans, Ports, and Rivers Institute. ASCE is a 501(c)(3) non-profit educational and professional society.

On November 7–8, the external review panel met in New Orleans with the IPET and was able to conduct its first on-site observations of the levee system from the air and on the ground.

II. OBSERVATIONS

On November 2, 2005, the ASCE and University of California/Berkeley teams released a joint report, “Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina on August 29, 2005.” As the title clearly indicates, this is a preliminary report. Any final conclusions on the failure of the New Orleans levees must await the study being conducted by the Corps’ IPET scheduled for release on July 1, 2006.

The complete preliminary report by the ASCE levee team and the NSF can be found at <http://www.asce.org/static/hurricane/orleans—report.cfm>.

The following observations are based largely on the joint preliminary report, as well as my own recent observations. What ASCE found in the field was very different than what we had expected, given the media reports. Rather than a few breaches through the floodwalls in the city caused largely by overtopping, we found literally dozens of breaches throughout the many miles of levee system. A number of different failure mechanisms were observed, including scour erosion caused by overtopping, seepage, soil failure, and piping.²

As geotechnical engineers, team members were particularly interested to find that many of the levee problems involved significant soil-related issues.

A. 17th Street Canal

At the 17th Street Canal breach, we observed intact soil blocks that had experienced large translation and heave. This movement would be consistent with a failure either of the soil embankment or the foundation soils beneath. There was no evidence of overtopping at this site. While we cannot yet determine conclusively the cause of the breach itself, this type of soil failure may well have been a significant contributing factor. Further investigation, together with analyses and review of the design and construction documents, should be of tremendous assistance in ultimately making these kinds of determinations.

B. London Avenue Canal—North

At the north breach on the London Avenue Canal, we observed a large displaced soil mass, which had been heaved nearly vertically over six feet, apparently indicating the toe of a rotational-type soil failure. Again, there was no evidence of overtopping at this site. Field inspection also showed a large amount of sandy soil deposited in the neighborhood landward of the breach, which is believed to be material from the foundation beneath the embankment together with material scoured from the canal bottom. This is consistent with the soil profiles provided to us which showed sand in the subsurface near this location. Under high water pressure, the flow through this type of material can be significant, which is known to cause internal stability problems.

C. London Avenue Canal—North, Across from Breach

Of particular interest was the levee section almost directly across from the north breach on the London Avenue Canal, where we observed a floodwall and underlying embankment that was in severe distress.

This site provided an excellent case study demonstrating multiple, concurrent failure mechanisms. It was observed that this section of floodwall was distressed to the point that it appeared that it might have been approaching failure when the water loading was relieved as the other breaches occurred. The wall was badly out of alignment and tilting landward; as a result of the tilt, there were gaps between the wall and the supporting soil on the canal or waterside. Also observed were evidence of soil movement, seepage and piping, as indicated by a series of sinkholes near the crest, together with “boils”³ and heave at or near the inboard toe⁴ of the embankment.

²Piping, sometimes referred to as internal erosion, is a channel caused by the flow of water through a dam or embankment. It may increase rapidly and cause catastrophic failure of the embankment.

³A boil (or “blow”) is a flow of soil, usually in the form of fine sand or silt, into the bottom of an excavation. The flow is forced in by water or water and air under pressure. It may increase rapidly and cause catastrophic failure.

⁴In the case of a dam or levee, the toe is the base of the slope on the side away from the water.

D. London Avenue Canal—South

To the south was another breach on the London Avenue Canal. That breach had apparently cut so deeply that huge volumes of sandy material had been scoured from the canal bottom and then deposited up to five feet deep extending hundreds of feet into the neighborhood. Very little evidence remained to be gathered at this site and the causes and mechanisms of the breach may never be known. It was, however, again demonstrated by high water marks that the floodwall most likely was not overtopped at this location.

E. Outside New Orleans

It is important that the impact of the levee breaches outside of the city of New Orleans not be overlooked. Many sections of the system were severely tested by overtopping from a direct onslaught of the storm surge. Many portions of these levees were breached or severely distressed, causing severe flooding and, in many cases, complete destruction of thousands of neighborhood homes. Some of the levee sections were nearly obliterated and were observed to have been constructed of highly erodable materials.

III. HURRICANE KATRINA: WHY DID THE LEVEES FAIL?

A. The Levee Failures

Hurricane Katrina was a catastrophic storm that made landfall in the Gulf Coast near the Louisiana and Mississippi border with wind speeds near 150 mph. But the damage in New Orleans due to the high winds and rain paled in comparison to the devastation resulting from the flooding.

The hurricane produced a storm surge that varied considerably depending on location, including the combined effects of orientation, geography, and topography with respect to the forces of the passing storm. Hydraulic modeling of the surge, verified for the most part by our own field observations of high water marks, show that essentially two significantly different levels of storm surge impacted the levee system.

As the storm passed to the east of New Orleans, the counterclockwise “swirl” of the storm generated a large surge from the Gulf of Mexico and Lake Borgne that impacted the eastern facing coastal areas of the New Orleans area and lower Mississippi delta. The surge was then concentrated into the channels of the Mississippi River Gulf Outlet (MRGO) that fed into the Inner Harbor Navigational Channel (IHNC). The funneling of the surge in these channels resulted in widespread overtopping of the levees.

In contrast, a somewhat separate surge that originated in Lake Pontchartrain was generated in part by the flow in from the Gulf of Mexico but also from the north winds across the lake. As shown by the models and field evidence, this surge, which impacted the lakefront and three canals within the central part of the city, was notably less severe. Field data indicated that the surge levels from the lake did not reach the elevation of the lakefront levees and was well below the top height of the floodwalls bordering the interior canals where three notable breaches occurred.

Where the storm surge was most severe, causing massive overtopping, the levees experienced a range of damage from complete obliteration to intact with no signs of distress. Much of the difference in the degree of damage can be attributed to the types of levees and the materials used in their construction. The majority of the most heavily damaged or destroyed earthen levees that we inspected were constructed of sand or “shell fill” which was easily eroded.

At some of these locations the earthen embankments were simply gone. Those with embedded sheetpiles fared only marginally better and were often breached as well. Further inland, in the western portion of the MRGO and along the Inner Harbor Navigation Canal, the degree of overtopping was less severe but again resulted in a number of breaches. Many of these breaches occurred through I-wall structures that were severely scoured on the landside as a result of overtopping. These scour trenches undermined the support of the levee floodwalls and reduced the ability of the walls to withstand the forces of the water on their outer surfaces. Localized concentrations of overtopping water flow or possible localized weaker soils may have been responsible for why certain portions of the system were breached while others remained intact.

Another commonly observed problem was the frequent presence of “transitions” between different sections of the levees. There were a number of different types of these transitions that appeared to have caused problems, including inconsistent crest heights, change in levee type (I-wall vs. T-wall), change in material (concrete, steel sheetpile, earth), and transitions where certain rights-of-way resulted in penetrations of the flood control system.

Where levees were overtopped, the weaker material at the point of transition (i.e., earth to concrete, sheetpile to concrete, earth to sheetpile) would be more susceptible to failure. Many of the problems we observed appear to have been related to transition details and were often exacerbated by inconsistent crest heights, particularly where the weaker material had the lower height. Many of these transitions were found at sections where infrastructure elements designed and maintained by multiple authorities, and their multiple protection elements, came together, and the weakest (or lowest) segment or element controlled the overall performance.

Finally, three major breaches, and at least one significantly distressed levee-floodwall section, were investigated at sites along the 17th Street and London Avenue canals which, as explained before, were clearly not overtopped.

Obvious soil failures within the embankment or foundation soils at or below the bases of the earthen levees had occurred at two of the breaches. At the distressed section, seepage and piping were evident. These types of soil instabilities appear likely to have been responsible for failure of these wall systems.

Evidence of piping erosion at one these sites serves to illustrate the severity of the underseepage at high water stages. Another possibility that also needs to be investigated, however, is the potential presence of a weak soil unit (either within the lower embankment, or in the underlying foundation soils) with sufficiently low shear strength that it may have failed.

Additional studies will need to be performed at these breached and distressed locations to better determine embankment and foundation soil conditions, and appropriate seepage flow and shear strength characteristics, so that the mechanisms that led to the observed failures at these sites can be conclusively determined.

B. Levee Repairs

As you know, the Corps of Engineers began making emergency repairs to the New Orleans levee system in the immediate aftermath of the hurricane. These repairs were necessary to complete the evacuation of the city, aid in the removal of the flood water, and restore order.

The Corps now has begun making longer term repairs to the levee system.

Construction crews are installing temporary cofferdams around the breached levees to keep water out while permanent repairs are made. The initial, emergency repairs are being removed.

The Corps then will install new sheet walls, presumably to greater depths than the original walls. The sheet walls will be T-walls, not I-walls; these will provide greater lateral support and better protection against seepage.

Not all repair issues appear to have been dealt with, however.

- The Corps will need to inspect the distressed floodwalls to determine whether to repair or replace them. It is our understanding that no decision has been made on how to manage the distressed and damaged flood protection systems at present.
- The Corps also will need to inspect apparently undamaged floodwalls and levees to determine if they have hidden structural damage or weaknesses.

C. Recommendations

Preparing the levees for the next hurricane season should include a review of how the system performed during Hurricane Katrina, so that key lessons can be learned to improve the performance of the system. Based on our observations, a number of initial comments are warranted concerning the rebuilding and rehabilitation of the levee system.

While levee failures may be expected when overtopping occurs, the performance of many of the levees and floodwalls may be significantly improved, and the likelihood of future failures prevented, with relatively inexpensive modifications of the levee and floodwall system.

The following specific points need to be dealt with immediately in New Orleans:

- The levees need additional overtopping protection at the inboard sides of the floodwalls to minimize erosion.
- Crest heights of the levees need to be planned in a systematic and deliberate way, so that if and when overtopping does occur, it occurs preferentially at the desired locations along any given section of levee's floodwall frontage where the walls are more robust or designed to better resist overtopping.
- Transitions should be improved so that they do not represent locations of potential weakness in otherwise contiguous perimeter flood protection systems.
- The storm surge that was funneled through the Mississippi River Gulf Outlet was a significant factor in the overtopping of the levee system. The Port of New Orleans and the Corps must carefully consider whether the danger posed to human

life and property by future storm surges down the Outlet warrants keeping the channel open, notwithstanding the already large investment in it.⁵

In addition, larger issues should be addressed as well.

- ASCE believes that Congress should enact a National Levee Inspection and Safety Program modeled on the successful National Dam Safety Program. The levee program should include a national inventory of levees, particularly those that protect large, heavily populated urban areas.

- ASCE supports the efforts to reduce coastal land loss in the Louisiana coastal area, an area that has been named America's Wetland because of its national importance. ASCE urges continued support of the existing program for Louisiana coastal wetlands, funded by the Coastal Wetlands Planning, Prevention, and Protection Act (CWPPPA). ASCE also supports the ongoing effort to implement the comprehensive Louisiana Coastal Area (LCA) Program, which will further reduce land loss and provide additional preservation.

- We must discourage new development in the floodplain unless there is a pressing need for it and adequate protection can be provided. Population centers on the Gulf Coast must be given a higher level of protection than most now have.

- We must use all the tools available to reduce damages. This means use of not only structural means such as levees, floodwalls, and dams, but also non-structural approaches such as flood resistant design, voluntary relocation of homes and businesses, revitalization of wetlands for storage, and use of natural barriers such as the Louisiana wetlands.

- Congress needs to consider seriously whether to establish a more stringent national flood control policy that emphasizes the need to protect human life from a 500-year flood.⁶

- ASCE believes Congress should establish an independent advisory panel to envision the future of the Gulf Coast and to recommend ways to begin the rebuilding of the areas that were devastated by Hurricane Katrina on August 29. The panel should consist of technical experts from a number of disciplines who would provide an objective review of all design and construction issues relating to the reconstruction of the areas covered by the President's major disaster declarations for Louisiana, Mississippi, and Alabama. The unpaid body would cooperate with and advise all Federal, State, and local agencies involved in the reconstruction effort in the affected region.

As we see it, the Advisory Group charter would:

- Work as the primary advisor to all state and local governments on the rebuilding of the region, with the primary goal of helping hundreds of thousands of present and future residents of the areas to enjoy a secure and prosperous future.

- Consist of experts from engineering, architecture, urban planning, and other design and construction-related fields.

- Develop recommendations that would include strategies to minimize the impact of future storm events and other natural hazards.

- Provide expert advice on the design and construction of the region's damaged public facilities, including port and harbor installations; lifelines; wastewater and drinking-water plants; airports and airfields; waste-management and disposal facilities; mass transit and public transportation services; roads, bridges, and tunnels; public buildings; and other key infrastructure.

- Ensure that the reconstruction efforts take into account the latest technologies in the prevention and mitigation of future harm to public and private buildings from severe windstorms and floods.

- Serve as link to Federal Agencies working in support of the reconstruction effort.

- Function in an advisory capacity only, having no authority to mandate particular design, construction, or environmental solutions.

⁵The 76-mile Mississippi River Gulf Outlet accounts for an estimated 3 percent of all shipping traffic in southeastern Louisiana. It was authorized by Congress in 1956 and built between 1958 and 1965 at a cost of \$92 million. Last year the Corps spent an estimated \$17 million to dredge the MRGO. Repairs to the Outlet in 1998 after Hurricane Georges totaled nearly \$42 million, according to one estimate.

⁶A 500-year flood is so big and rare that it will normally happen only once every 500 years. That doesn't mean that a 500-year flood can't happen the year after a 500-year flood. Every flood season has exactly the same chance—one in 500—of producing a 500-year flood, even in area that experienced a 500-year flood the season before. In other words, it is the flood that has a 0.2 percent chance of occurring every year. A 100-year flood, on the other hand, is used by the National Flood Insurance Program as the standard for floodplain management and to determine the need for flood insurance. A 100-year flood is based on a 1 percent chance of a flood's occurring in a given year.

IV. CONCLUSION

Other potentially important lessons will be learned in the months ahead, and some of these are also likely to be useful in moving forward with the ongoing repair and long-term rebuilding of the New Orleans regional flood protection systems.

As much of the population is currently being permitted to re-occupy portions of the New Orleans area, doing everything possible to ensure the safety of these people and their neighborhoods must continue to be the highest priority.

Mr. Chairman, this concludes my testimony this morning. We would be pleased to answer any questions you may have.

RESPONSES OF LARRY ROTH TO ADDITIONAL QUESTIONS FROM SENATOR VITTER

Question 1. Do you believe that there are problems in the current Corps of Engineers project process that may have contributed to the failures in south Louisiana?

Response. There do not appear to be problems in the Corps process right now. There is a problem with the organizational and institutional communication and coordination that occurs between the Corps and the local levee boards.

The Corps has a very robust quality-control and quality-assurance process. At this time we cannot blame the Corps for a communications breakdown. There will not be enough information available until the Interagency Performance Evaluation Task Force (IPET) report is completed in June 2006.

Question 2. In the media, some investigators suggested that the Corps was less than forthcoming with some of the requests for information and interviews. Could you share the experiences of the ASCE team in this regard?

Response. The Corps was extremely cooperative in granting access to the sites in a timely fashion. While there were requests for information that were not immediately handled, the Corps was under pressure to get the levees back up and running. Much of the information in question is now published on the Corps Web site at <https://ipet.wes.army.mil/>.

Question 3. On the London Avenue Canal, there were a number of failures on one side of the canal but not the other. Can you explain why this could have occurred?

Response. It's not possible at this time to explain why the failure was one-sided. That question will have to be answered by the IPET report.

Question 4. Your testimony cites composition of soils as an important consideration in ASCE's investigation. What role do you think soil played in the floodwall failures?

Response. The erosive nature of the soils around the levees was a major factor in the floodwall failures where sever overtopping occurred. In the case of foundation failures, we understand the "how" but we do not yet understand the "why" of the failures. The "why" will be answered by the IPET report.

Question 5. What are your recommendations on how the drainage canals are redesigned in future protection systems?

Response. The best way to redesign the canals would be to effectively eliminate them. If the pumping stations were moved from the south end of the canal and rebuilt on the lakeshore so that the canals were no longer necessary, it would prevent any storm surges from the lake moving down the canals and causing problems.

Question 6. You referenced the highly-erodible materials used in composition of some levees outside of New Orleans. If there is widespread use of these materials in our levee systems, what steps could be taken to strengthen these structures?

Response. This problem stems from the fact that when levees are built the materials used in construction come from nearby due to the high cost associated with hauling building materials in from far away sites. Since levees are built in a floodplain then the local soil used in construction is, generally speaking, a fine-grained alluvial soil that is not the best suited for levee construction.

That said, levees could be hardened for protection from erosion by adding stronger materials such as rock, stone, or concrete.

RESPONSE BY LARRY ROTH TO AN ADDITIONAL QUESTION FROM SENATOR JEFFORDS

Question. It appears that there is virtually unanimous agreement that the Mississippi River Gulf Outlet (MRGO) should be closed. Even the Louisiana legislature has passed resolutions in support of closing the MRGO. In your testimony, you explain that this channel accounts for only THREE PERCENT of all shipping traffic

in southeastern Louisiana. It appears to be an antiquated project that presents a serious hazard to New Orleans. Can you give me your perspective on what barriers there are to closing MRGO?

Response. There are no engineering barriers to closing the MRGO. The decision whether to leave the Outlet operating or not will be based on the economics of the region, the closing's impact on the environment, and political considerations of the public and government officials.

STATEMENT OF JOSEPH SUHAYDA, EMERITUS ENGINEERING PROFESSOR, LOUISIANA STATE UNIVERSITY

My name is Joe Suhayda and I pleased to appear before you today to testify about incorporating the preliminary findings about the failures of the levees protecting New Orleans and adjacent areas into a plan for restoring hurricane flood protection to the area. This is certainly a critical and timely issue since, while there is a need for immediate action to rebuild the now non-functional system, recreating the vulnerabilities of the past only guarantees future disasters.

I would like to describe some of the suggestions I have been making to provide interim flood protection for the city that will bridge the gap between the current condition of the flood protection system and the future improved conditions that may be decades away. These suggestions result from my having been involved with hurricane flood prediction and flooding issues in Louisiana for several years. I worked for 30 years as a faculty member at Louisiana State University including 20 years in the Civil and Environmental Engineering Department teaching hydraulics, coastal engineering and marine geotechnology. I was a senior consultant to the Hydrology and Hydraulics Branch of the New Orleans District of the Corps of Engineers for 4 years in the late 1990s and I have also worked under contract to the FEMA, the Louisiana Office of Emergency Preparedness and several individual parishes concerning hurricane flood preparedness.

I would first like to review a few significant points about the preliminary findings concerning the levee failures. These findings have been presented in testimony before Congress and in a recent report prepared by the American Society of Civil Engineers, to which I refer you for details. What I want to emphasize are three the major findings which I feel have particular relevance to the restoration of hurricane flood protection for the City of New Orleans and the surrounding area. These significant findings are:

1. The hurricane flooding protection system protecting the city and the adjacent areas consisted of a complex array of canals, levees and floodwalls that were geographically and administratively distinct. Subcomponents of this system, the levee districts, existed for the Jefferson Parish Lakefront, the Orleans Parish Lakefront, Orleans Parish (New Orleans East), St. Bernard Parish and Plaquemines Parish. The levee system was designed to provide variously 100 year and Category 3 flood protection. The Lake Pontchartrain and Vicinity Project was initially authorized by Congress in 1965 and had not been completed prior to Katrina.

2. The hurricane surge and waves produced by Katrina varied considerably over southeastern Louisiana, so that no two levee districts were subject to the same hurricane conditions. In locations south of the city the hurricane conditions exceeded the project design capabilities, while along the Lake Pontchartrain the hurricane conditions appeared to be at or lower than the project design conditions.

3. There were dozens of breaches of levees and floodwalls throughout the system resulting from overtopping, seepage, soil failure and piping causing miles of levees and floodwalls to be either severely damaged or destroyed.

4. It is currently not certain that all of the levee and floodwall breaches requiring rebuilding can be repaired to the pre-Katrina Category 3 protection before the start of the hurricane season in 2006. Furthermore, raising all floodwalls and levees to a greater level of protection greater than Category 3 will take many years, perhaps decades, to accomplish.

Reviewing these findings raises two issues. The first issue is the appropriateness of the current authorization by Congress limiting the city to Category 3 flood protection. This authorization has been repeatedly cited by the Corps of Engineers as the primary factor limiting their future actions. However, this level of protection has been looked at for some time as being inadequate. A higher level of hurricane flood protection can be justified on a consistency argument alone. The river levee system in the city is designed to protect from a 1 in 800 year flood, while the current hurricane protection system was designed to protect from a 1 in 200 year flood, or about 4 times the riverine risk. The current authorization for hurricane protection projects is now out of date because the City of New Orleans and the surrounding areas have

undergone major changes. The landscape surrounding the city has been extensively altered due to continuing wetland loss and accelerated by Katrina. Also, the demographics and economy of the city have been changed considerably due to Katrina. A commitment by Congress now to authorize the Corps to begin to develop Category 5 flood protection for the City of New Orleans and adjacent areas would show that we have truly learned that the Category 3 protection was inadequate. It would also eliminate the current uncertainty about what the long-term Federal commitment is to providing hurricane flood protection to the city.

Because of the time delays in providing either Category 3 or higher flood protection, the second issue I want to raise is the consideration of some form of immediate interim flood protection. Interim flood protection would supplement the long term plans for rebuilding of the levee/floodwall system. This interim protection could act as an incentive to bring people back into the protected areas and establish the physical basis for economic and cultural recovery. Interim flood protection would be done to give us time to carefully develop a long term plan and would not interfere with the implementation of the long term plan. The interim flood protection approach is based upon the fact that flood protection can be achieved by augmenting the traditional levee and floodwall system with new approaches. These approaches include:

1. Recognizing the fact that the various levee districts comprising the hurricane flood protection system now have different problems, needs and opportunities for rebuilding and should be treated separately rather than as one big system.

2. Additional flood protection needs to be added existing levees and floodwalls that were not extensively damaged to minimize future damage to these structures.

3. Internal flood control barriers need to be created that would take advantage of existing roadways and natural ridges to compartmentalize areas within a levee district and prevent flood waters from a single overtopping or breach from flooding the entire district.

4. Flood proofing of critical individual infrastructure facilities needs to be accomplished with flood barriers in areas where district wide protection cannot be achieved. These flood proofing activities would concentrate on those facilities critical to recovery including governmental buildings, hospitals, schools, businesses and densely populated residential areas.

These approaches could be implemented selectively to meet the specific needs of the various levee districts. For example, the Jefferson Parish Lakefront levee district received little flooding and the floodwalls, levees and pumps survived essentially intact. To increase the protection of this undamaged area, flood barriers could be placed atop the lake shore levees to immediately increase the flood protection to Category 3 or higher. The flood water passing through the canal breaches in Orleans Parish did not flood Jefferson Parish because it was prevented by the 17th Street Canal floodwall and by a topographic feature called the Metairie Ridge. A flood barrier should be placed on the ridge to provide increased protection from flooding originating in the Orleans Parish.

In the Orleans Parish Lakefront district the emergency action taken by the Corps to close the canals at the lake with sheet piling should be continued. This would eliminate the currently suspect floodwalls in the district as a part of the hurricane protection system. Additional pumps could be placed at the lake shore to reduce to loss of drainage capacity during the summer months. The height of lakeside levees could be increased using flood barriers to obtain Category 3 or greater flood protection. Barriers could also be used along the natural Metairie and Gentilly Ridges to protect the Central Business District and French Quarter from any from flooding coming from Lake Pontchartrain. The floodwalls along the Industrial Canal can be protected from scouring that would result from overtopping by armoring the landward side of the floodwalls. For the New Orleans District, St. Bernard Parish and Plaquemines Parish, where extensive levee damage occurred, interior flood protection barriers could be deployed to establish flood free areas and protect critical infrastructure.

The designs and structures needed to achieve interim protection are readily available. Flood barriers that could be used for interior flood protection and flood proofing have been recently tested by the Corps of Engineers in both field and laboratory settings. These flood barriers are rapidly deployable and removable and are being developed as a replacement for sand bags. This same technology is already being used in repairing floodwalls along the London Avenue and Industrial Canals to make them less prone to erosion. These barriers have also been used at a variety of location nationwide and have been deployed in Louisiana prior to Hurricane Katrina along the East Jefferson Levee District levees at the lakeshore and in Slidell.

This concludes my testimony and I will be pleased to answer any questions you have.

RESPONSES BY JOSEPH N. SUHAYDA TO ADDITIONAL QUESTIONS FROM
SENATOR JEFFORDS

Question 1. In your testimony you state that you believe that the levee districts should be treated individually as the rebuild continues. That seems counter-intuitive when you consider the findings that in many cases, the transition spots between levee systems were found to be weaker points in the design. This seems to suggest that a more comprehensive approach to levee design and construction would make sense. Can you explain?

Response. I was using the term "levee district" to refer to each of the separate structural components that make up the levee system protecting New Orleans and the surrounding area, not the administrative agencies, i.e., the levee boards. Organizationally I believe that the levee boards should be either replaced by a statewide agency or be required to adhere to a statewide, unified levee plan and standard. In terms of the physical subdivisions or components of the levee system, the "polders", I wanted to emphasize the each polder has a distinct location, protects a unique mix of people, businesses and residences, and has a different exposure to the hurricane flooding threat. What we learned is that levees and floodwalls in the various polders did not receive the same type or amount of damage, and that the threat to public safety varied greatly among the polders. Therefore, I think the polders should be treated distinctly in terms of their priorities for rebuilding, the levels of short term and long term protection, and schedule of rebuilding and improvement. For some polders Category 3 protection may be appropriate, while for others Category 5 may be justified. Since we have so many polders, i.e., levee system subdivisions, in Southeast Louisiana and may actually be adding more polders across the state, I strongly believe we should not take the approach that "one size fits all" that is, that the same level of protection is necessary for all of the separate polders.

Question 2. I have been reading some of your previous analysis of the potential risk to New Orleans should a major storm arrive there. I am particularly interested in your predictions about the mix of toxic chemicals that would occur should the entire city become flooded, allowing the mixing of industrial and household chemicals. Given what you have observed in New Orleans, do you believe your prediction has come true, to what extent, and do you believe the actions taken by the EPA to identify the problem and warn people are adequate?

Response. The prediction was overstated. There was some initial concern about water pollution that adversely affected rescue operations. The most widely reported health effect of being in the city right after the hurricane was a respiratory irritation named the "Katrina Cough". The quality of the vast amount of the water in the city and that was pumped into Lake Pontchartrain appears to have been no worse than that associated with a heavy rainfall. There were a few locations, such as at the Murphy Oil refinery, where there were very high levels of contamination. I think EPA and the State of Louisiana did an exemplary job of quickly and openly providing information about the problem.

Question 3. In your testimony, you state that you believe that the levee districts should be treated individually as the rebuild continues. That seem counter-intuitive when you consider the findings that in many cases, the transition spots between levee systems were found to be weaker points in the design. This seems to suggest that a more comprehensive approach to levee design and construction would make sense. Can you explain?

Response. See 1 above for answer.

RESPONSES BY JOSEPH N. SUHAYDA TO ADDITIONAL QUESTIONS FROM
SENATOR VITTER

Question 1a. In your testimony, you suggest that an improved hurricane protection system for south Louisiana may be decades away. What makes you believe that this will take decades?

Response. This is based upon the performance of the Corps of Engineers in designing and constructing the levees, and Congress willingness to fund the construction. The authorization for the Lake Ponchartrain and Vicinities Project was in 1965, with an initial estimate of about 15 years to complete the project. The Corps was still redesigning the project into the 1990's and the most recent pre-Katrina estimate of a completion date was 2015. Thus the original Category 3 project was extended to about a 50-year duration. Improving to a Category 5 level of protection will present even more difficult engineering and construction challenges than did the Category 3 system. Although the numbers have varied, I have heard members

of the Corps themselves say it will be as long as 30 years before the improvement to Category 5 protection could be accomplished. Another problematic issue is the consistency of the Congressional appropriations to fund the improvements. According to the New Orleans District the funding for the Category 3 project for 2005 were "insufficient to fund new construction contracts" and that the 2005-2006 funding shortfalls "will prevent the Corps from addressing pressing needs". If the levee improvements have a cost of \$ 6 billion over a 30 year period, this requires an average annual appropriation of \$ 200 million. Given that the outlook for the next several years for the federal budget is a dire, I think it realistic to anticipate some funding problems.

Question 1b. What suggestions do you have for streamlining or expediting the process to allow for this goal to be accomplished more quickly?

Response. There are some physical limitations on the rate that levees can be constructed that derive from the properties of the soils used in constructing the levees. Levees just take decades to be completed. However, changes in the design or delays in funding could also significantly delay completion of a project, and these are controllable. I think it is important initially to carefully develop the plan for the improved protection so that we can avoid procedural delays. Also, if it were possible to commit federal funding on a longer cycle than annually, then the Corps could maintain a more consistent construction pace.

Question 2a. If I understand your testimony, you are advocating the continued use of the levee board concept. The state legislature recently took steps to centralize this authority. Could you explain your support for the levee district concepts?

Response. See my answer above to Senator Jefford's first question. To repeat, I think the levee districts, i.e., the "polders", need to be considered as separate and unique geographic entities, but should be planned, constructed and managed to statewide standards. I think the levee boards should be reorganized and/or held to state and federal performance standards.

Question 2b. Based on your investigation and knowledge, do you believe the actions of the Orleans Levee Board contributed to the floodwall failures in New Orleans?

Response. I don't know of any specific actions of the Orleans Levee Board that contributed to the failure of the 17th St. and London Ave. floodwalls. In both cases there were reviews of the designs by several engineering companies and several levels within the Corps of Engineers that also supervised and approved the design and construction. Maintenance of the floodwalls by the levee board may have been an issue that could have been improved upon, but I don't know of any specific evidence that a maintenance deficiency caused the failures. The reason for the failures is being investigated and I think many of the initial explanations have been shown to be wrong.

Question 3. Your testimony states that you are uncertain if it is possible to restore the levees and floodwalls in south Louisiana to a Category 3 level of protection before next hurricane season in June. The Corps of Engineers has stated that they intend to restore protection by June. What causes your reservations?

Response. Since the situation on the ground is changing so rapidly, I must qualify my answer. First, it appears that the Corps has recently indicated a completion of the restored protection will be in late August 2006. Second, it also appears that the 17th Street, Orleans and London Ave. canals will be closed at the lake. So fixing the floodwalls lining the canals may be unnecessary. Third, in general the levee system was not at a Category 3 level of protection before Katrina, and it was estimated that it would take several years of work to bring the system to the authorized level of protection. The commitment by the Corps I understood was to return the levee system to the pre-Katrina level of protection and not to a never achieved Category 3 level.

Question 4. Your written statement suggests that, "a higher level of hurricane flood protection can be justified on a consistency argument alone". Could you please explain this statement?

Response. The city is protected from river flooding to the level of threat of a 1-in 800-year flood, called the Project Flood. This equates to an annual risk of .125 percent. The protection from hurricane flooding was to a level of a 1-in 200-year surge, which equates to an annual risk of .5 percent. Thus the risk to the city of flooding from hurricanes was about 4 times greater than for river flooding. The hurricane levees and floodwalls are in general about 10 feet lower than the river levees. I think the level of risk that the federal government is willing to subject the city to should be the same for both sources of flooding.

Question 5. You suggested that the hurricane protection system designed for the New Orleans area is out of date. Could you share with the committee your vision of a new protection system?

Response. A new protection system would be along the lines of the Dutch system, that is, redundant flood protection. Keep in mind that the hurricane flood threat includes both surge and waves. The new hurricane flood protection system would consist of barrier islands, wetlands, wave breakwaters, levees and floodwalls, interior flood control, and flood proofing of individual high value facilities. At the shoreline would be the barrier islands which would limit the amount of water and wave action moving inland. Inland of the barrier islands would be specially restored sections of dense wetlands. Inland of the wetlands would be a wave breakwater structure and then a surge levee. The surge or main levee would define the boundary of the "polder" area. Inside of the levee system would be interior structures to limit and control the spread of any flood waters that either overtop or breach the main levees. Finally, high value facilities such as shelters, governmental buildings, hospitals, refineries, etc., would be flood proofed with local flood barriers. Structures to temporarily close navigation channels and natural passes to prevent movement of flood waters inland would also be a feature.

Question 6. You appear to support the concept of "interim flood protection" while the Corps continues to work on a long term plan for greater protection. Could you expand upon this concept?

Response. The estimates are that the Category 5 flood protection will not be achieved for decades. This would leave the city, the population and any rebuilding that occurs again vulnerable to Category 4 and 5 flooding for many years to come. I think we will need some kind of improved hurricane flood protection that can be accomplished in a few years and function to provide more than Category 2-3 protection until the Corps projects are completed. This could be done by providing interior flood control and flood proofing of selected facilities.

STATEMENT OF ROBERT R.M. VERCHICK, GAUTHIER-ST. MARTIN EMINENT SCHOLAR
CHAIR IN ENVIRONMENTAL LAW, LOYOLA UNIVERSITY NEW ORLEANS, BOARD MEM-
BER AND SCHOLAR OF THE CENTER FOR PROGRESSIVE REFORM

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to testify on how preliminary findings on the failure of the levees should be incorporated into future plans for hurricane protection. I testify today as an expert in environmental law and policy and a resident of New Orleans.

As you know, I am an evacuee. My wife and children are living this fall in the state of Washington, and I have taken up temporary residence in Houston, Texas, where my Law School, Loyola New Orleans, is continuing its fall semester in space donated by the University of Houston.

I hold the Gauthier-St. Martin Chair in Environmental Law at Loyola University New Orleans, where I teach on issues concerning environmental law and natural resource management. One of my primary areas of research and teaching concerns resource issues in southern Louisiana, including the state's coastal wetlands and levees. I have also been a visiting professor of law at Aarhus University in Denmark and a guest professor at Beijing University in China. I hold an A.B. degree from Stanford University and a J.D. degree from the Harvard Law School. My expertise is in environmental law and property law. I am the Chair of the Environmental Law Section of the Association of American Law Schools (AALS) and immediate-past Chair of the Property Section of the AALS.

Finally, I am a scholar and board member of the Center for Progressive Reform (CPR). Founded in 2002 as the Center for Progressive Regulation, CPR is a 501(c)(3) nonprofit research and educational organization dedicated to protecting health, safety, and the environment through analysis and commentary. CPR is a network of university-affiliated academics with expertise in the legal, economic, and scientific issues related to regulation of health, safety, and the environment. CPR believes sensible safeguards in these areas serve important shared values, including doing the best we can to prevent harm to people and the environment, distributing environmental harms and benefits fairly, and protecting the earth for future generations. CPR further believes that people play a crucial role in helping the private and public sectors make decisions that result in improved protection of consumers, public health and safety, and the environment.

Last September, CPR published two reports on Hurricane Katrina, the first titled "An Unnatural Disaster: The Aftermath of Hurricane Katrina," and the second titled, "Broken Levees: Why They Failed." Both are available on CPR's Web site at: <http://www.progresivereform.org>.

A. INTRODUCTION

My testimony today focuses on how preliminary findings on the failure of the levees should be incorporated into future plans for hurricane protection. After reviewing what we now know about the failures of Louisiana's levees and the destruction of its protective wetlands and barrier islands, I draw four lessons, each accompanied with a recommendation:

1. Focusing only on levees is a fool's gamble. Any new hurricane protection vision must be integrated and must consider simultaneously levee and gate construction, wetlands restoration, habitat preservation, canal navigation, and patterns of residential and commercial development.

2. Strong plans are adaptive plans. A new hurricane protection vision should incorporate a formal mechanism by which an independent, scientific board regularly assesses the design, condition, and performance of hurricane protection features (from levees to barrier islands) to call attention to areas in need of maintenance or improvement.

3. What's good for the environment is good for hurricane protection. A new hurricane protection vision must adhere to current environmental and procedural standards, including the National Environmental Policy Act (NEPA).

4. The Corps can't do it alone. Effective hurricane protection in the Gulf may require the establishment of an independent commission made up of Federal, State, and local officials, with expertise in policy, land use, science, and engineering to supervise the work of the Corps and other governmental and private entities whose work relates to hurricane protection.

B. BROKEN LEVEES: PREDICTIONS THAT CAME TRUE

The failure of the levees in New Orleans was catastrophic for the city and for its most vulnerable citizens. In the aftermath of Hurricane Katrina, it is important to understand why the levees failed and what actions, had they been taken, would have prevented, or reduced, the flooding of New Orleans.

1. *The Facts: Inadequate Levees*

New Orleans is protected from Lake Pontchartrain and Lake Borgne, which are located almost side-by-side on the North side of New Orleans, by an interconnected series of levees that extends along the lakes. (A map of the lakes and levees by the Times Picayune can be found at <http://www.nola.com/hurricane/popup/nolalevees—jpg.html>.) These levees are considerably smaller than the ones that protect New Orleans from flooding of the Mississippi. While the levees on the Mississippi average 25 feet above sea level, these levees range from 13.5 to 18 feet above sea level in height. Another series of somewhat lower levees provides protection to St. Bernard Parish, which is located to the north and east of New Orleans, from Lake Pontchartrain on the north and from Lake Borgne and the Gulf on the east. Parts of the parish are located between the two lakes.

Because New Orleans is below sea level and rapidly sinking, rainwater that flows into the city must be removed not by natural drainage, but with huge pumps that force the water to move along three man-made canals, called "outfall canals," to Lake Pontchartrain. The canals are lined with concrete walls that prevent the water from spilling into the city. Water flowing through the canals is nearly as high as the rooftops of some houses adjoining the canals.¹ All of the levees were built by the Corps and are maintained by various local levee districts.²

In addition to the drainage canals, the Corps of Engineers constructed two very large canals that permit ocean-going vessels to move from the Mississippi River through the city to Lake Pontchartrain or the Intracoastal Canal near Lake Borgne. The Industrial Canal slices north/south across the city between the river and the lake at the point where they are closest to each other. The MRGO canal bisects the Industrial Canal and travels east/west to the Intracoastal Canal near Lake Borgne. The shipping canal levees consist primarily of concrete floodwalls and earthen levees.

The water that flooded New Orleans did not flow over the levees situated between the lake and the city. Instead, it appears that the surge flowed up the 17th Street and London Avenue canals and caused floodwall breaches along the 17th Street canal and the London Avenue canal.

The city also flooded because the levee system did not protect it from the "end around" exposure that occurred during Hurricane Katrina. The hurricane surge en-

¹Graphic, First Line of Defense: Hoping the Levees Hold, TIMES-PICAYUNE (New Orleans), available at <http://www.nola.com/hurricane/popup/nolalevees—jpg.html>.

²Id.

tered Lake Borgne from the Gulf of Mexico and proceeded up the MRGO canal to the Industrial canal in the heart of New Orleans. Hurricane Katrina appears to have destroyed as much as 90 percent of the levees and floodwalls along the MRGO canal in St. Bernard Parish as it pushed up the narrowing canal from Lake Borgne to the conjunction of the MRGO canal with the Industrial canal. Colonel Richard Wagenaar, the Corps head engineer for the New Orleans district, reported that the eastern levees were “literally leveled in places.”³

2. *We Knew This Would Happen*

Not long after the levees broke and water from Lake Pontchartrain on the north and Lake Borgne on the east began to fill New Orleans, President Bush told television correspondent Diane Sawyer that no one could have foreseen the breach of those levees.⁴ In fact, over a period of many years, scientists had predicted that a strong storm could also breach the levees. Scientists especially feared that even a relatively weak storm coming from the right direction would push a wall of water into the heart of New Orleans from Lake Borgne through the funnel-shaped MRGO canal and into the Industrial canal, destroying the levees along the canal and flooding much of St. Bernard Parish and the Lower Ninth Ward. It now appears that this is exactly what happened.⁵

Moreover, the risks posed by the MRGO canal were evident. In 2002, the Corps of Engineers acknowledged that “[t]he MRGO levee is more likely to be affected than the area on the lake itself.”⁶ Proponents of closing the canal pointed out that, with the erosion of the wetlands in the unleveed stretches south and east of the city, it had “evolved into a shotgun pointed straight at New Orleans.”⁷

3. *Bad Planning and Skewed Priorities*

The failure to protect New Orleans resulted from inadequate planning by the Corps to save the city, and from the failure of Federal Government to fund badly needed improvements once those limitations were recognized. Neither the Corps nor Congress adequately accounted for the loss of life and property that would occur if a catastrophic hurricane hit New Orleans.

The hurricane protection plan that was implemented after 1985 by the Corps was designed to protect the city against the “standard project” hurricane that roughly corresponds to a fast-moving Category 3 storm.⁸ Scientists had for years prior to the storm predicted that the levee system could not withstand a Category 4 or Category 5 storm.⁹ Hurricane Katrina struck the Louisiana/Mississippi coast as a Category 4 storm, although its force had weakened to a Category 3 storm when it hit New Orleans.

Moreover, although the MRGO canal was a primary cause of the flooding, it is seldom used and heavily subsidized by taxpayers. The canal, which was completed in 1968, is a deep draft seaway channel that extends for approximately 76 miles east and southeast of New Orleans into Breton Sound and the Gulf of Mexico. It was designed to shorten the distance for ships from the eastern shipping lanes of the Gulf to New Orleans, but it has never lived up to its predicted economic expectations. Less than 3 percent of the New Orleans port’s cargo traffic uses the MRGO; this amounts to less than one ship per day.¹⁰ According to one estimate, the government spends \$7 to \$8 million per year (about \$10,000 for every large vessel that uses the canal) just to maintain the canal.¹¹

³Ralph Vartabedian, Much Wider Damage to Levees Is Disclosed, L.A. TIMES, September 13, 2005, available at <http://www.latimes.com/news/nationworld/nation/la-na-corps13sep13,0,5962987.story?coll=la-home-headlines> (last visited September 21, 2005).

⁴Dan Froomkin, White House Briefing: A Dearth of Answers, WASH. POST, September 1, 2005, available at <http://www.washingtonpost.com/wp-dyn/content/blog/2005/09/01/BL2005090100915.html?nav=rss-politics> (last visited September 21, 2005).

⁵Michael Grunwald, Canal May Have Worsened City’s Flooding, WASH. POST, September 14, 2005, at A21.

⁶Jerry Mitchell, E-Mail Suggests Government Seeking to Blame Groups, CLARION-LEDGER (Miss.), September 16, 2005, at A1, available at <http://www.clarionledger.com/apps/pbcs.dll/article?AID=/20050916/NEWS0110/509160369/1260> (last visited September 21, 2005) (quoting Corps of Engineers spokesperson John Hall); John McQuaid & Mark Schleifstein, Evolving Danger, TIMES-PICAYUNE (New Orleans), June 23, 2002, at J12.

⁷McQuaid & Schleifstein, Evolving Danger, *supra* note 31.

⁸Mitchell, *supra*; McQuaid & Schleifstein, Evolving Danger, *supra*.

⁹Mitchell, *supra*; McQuaid & Schleifstein, Evolving Danger, *supra*.

¹⁰Grunwald, *supra*.

¹¹LAKE PONTCHARTRAIN BASIN FOUND., MARTELLO CASTLE WETMAAP, Background Information, available at <http://wetmaap.org/Martello-Castle/Supplement/mc-back-ground.html>.

Although the vulnerability of New Orleans to a catastrophe was well known and widely predicted, the Corps floundered in its efforts to enhance the protection of New Orleans from Lake Pontchartrain. In an award winning series of articles on the levee system, *The Times-Picayune* concluded that the Corps of Engineers declined to move forward with enhancements to the levee and floodwall system because “no clear bureaucratic mandate exists for reassessing the blueprints once levees are built.”¹² For example, an attempt in 1996 to reevaluate the Lake Pontchartrain levees broke down in disputes over modeling and other bureaucratic disagreements.¹³ When Congress appropriated money to protect New Orleans better, the Corps was not been in a hurry to get the job done. For example, Congress in 1999 appropriated money for a \$12 million study to determine how much it would cost to protect New Orleans from a Category 5 hurricane, but the study had not even been launched as of September 2005.¹⁴

In addition, the Bush administration failed to fund Corps requests. Mike Parker, a former Republican Congressman from Mississippi who was until 2002 the chief of the Corps, was forced to resign when he publicly stated to the Senate Budget Committee that the national interest was being harmed by President Bush’s proposal to cut over \$2 billion from the Corps’ \$6 billion budget.¹⁵ The Bush administration rejected an Corps request for \$27 million to pay for hurricane protection projects along Lake Pontchartrain and proposed a budget of only \$3.7 million. Congress ultimately appropriated \$5.7 million for the projects, but the Corps still had to delay seven levee improvement contracts.¹⁶ After Hurricane Katrina struck, Mr. Parker stated that President Bush had not adequately funded improvements to the very levees in New Orleans that had been breached; indeed, Mr. Parker stated that had full funding been authorized “there would be less flooding than you have.”¹⁷ An official Corps memo dated May 2005, long after Parker left the agency, seemed to corroborate this possibility. It stated that the Bush administration’s funding levels for fiscal years 2005 and 2006 were not enough to pay for new construction on the New Orleans levees.¹⁸

Although the current administration bears blame for the failure to fund critical levee improvement projects, the truth is that improving the Lake Pontchartrain levees has been a low priority for many administrations, Democratic and Republican, and for Congress. The Bush administration and Congress have had other priorities over a longer period of time than the last four years. In fact, it seems clear that even the Louisiana congressional delegation has on occasion insisted that the Corps direct its resources to projects like a \$194 million project for deepening the Port of Iberia and replacing the lock on the Industrial canal.¹⁹

The Bush administration and Congress are influential in setting budget priorities because the Corps is very reluctant to participate in the process of setting priorities for its projects. Moreover, once the Corps has determined that the benefits of a proposed project exceed its costs, the Corps leaves it to Congress to decide through the appropriations process which projects receive funding and which do not.²⁰ Congress is ordinarily willing to consider passing appropriations for large public works projects, however, only in the wake of major disasters or after years and years of study.²¹

4. Poor Design and Construction

Sadly, it now appears that one of the most direct causes of levee failure was faulty design and construction. There are now strong indications that the critical floodwalls along the outlet canals on 17th Street and Industrial Avenue did not breach because the water surged over them and eroded away their support but because they were not capable of withstanding even the surge of a Category 3 hurri-

¹² McQuaid & Schleifstein, *Evolving Danger*, supra.

¹³ Id.

¹⁴ Andrew Martin & Andrew Zajac, *Corps: Lack of Funds Did Not Contribute to Flooding*, CHI. TRIB., September 2, 2005, at 1.

¹⁵ John McQuaid & Mark Schleifstein, *Shifting Tides*, TIMES-PICAYUNE (New Orleans), June 26, 2002, at 14.

¹⁶ Andrew Martin & Andrew Zajac, *Flood-Control Funds Short of Requests*, CHI. TRIB., September 1, 2005, at 7.

¹⁷ Id.

¹⁸ Reuters, *Andy Sullivan, Budget Cuts Delayed New Orleans Flood Control Work*, September 1, 2005, available at <http://www.alertnet.org/thenews/newsdesk/N01279059.htm> (last visited September 21, 2005).

¹⁹ Michael Grunwald, *Money Flowed to Questionable Projects*, WASH. POST, September 8, 2005, at A1.

²⁰ Id.

²¹ McQuaid & Schleifstein, supra.

cane.²² (In contrast, evidence suggests that the Industrial Canal levee was, in fact, topped.) According to Ivor van Heerden, Deputy Director of Louisiana State University's Hurricane Center, his investigative team found no fewer than 27 major breaches in the of the canal levees.²³ The 17th Street levee appears to have ruptured in response to storm surges no stronger than those associated with a Category 1 storm.²⁴

Independent engineers have said that pockets of swampy soil and shallow steel pilings contributed to ruptures in the levees' earthen walls.²⁵ Preliminary findings suggest that while the Corps's design for the 17th Street levee required steel pilings buried 17 feet below sea level, the actual pilings were buried only 10 feet below sea level.²⁶ Earlier this month, an engineering expert told a Congressional panel that "malfeasance" may have also played a role in levee failure.²⁷ As a result, the Corps and its contractors are now targets of civil and criminal investigations.²⁸

C. WETLANDS POLICY AND EROSION: DECADES OF NEGLECT

1. *The Importance of Coastal Wetlands*

It is impossible to think about hurricane protection in Louisiana without also thinking about coastal wetlands. Just as any discussion of automobile safety must go beyond seatbelts, any discussion of hurricane protection must include discussions of marshes, swamps, and navigational channels.

Louisiana's coastal plain contains one of the largest expanses of coastal wetlands in the contiguous United States.²⁹ Sadly, 90 percent of the nation's coastal wetlands loss occurs here too.³⁰ Built by the deltaic processes of the Mississippi River, Louisiana's coastal plain hosts an extraordinary diversity of coastal habitats, ranging from natural levees and beach ridges to large swaths of forested swamps, to freshwater, intermediate, brackish, and saline marshes. These features which nourish wildlife, filter water, and dampen storm surges help make the coastal plain, to use the Corps' words, one of "the most productive and important natural assets" in the country.³¹

While most people do not realize it, one of the most important services provided by coastal marshes involves storm protection. Imagine blasting water through a garden hose at full force onto a cement driveway. The water splashes and surges, fanning out in many directions. Now imagine spraying water from the same hose onto a thick, dense lawn. The difference between the cement and the lawn is the difference between a storm path composed of open water and denuded coast and one composed of lush forests and marsh. Louisiana's coastal wetlands act as vast sponges, absorbing billions of gallons of rainfall and shielding people and property from storms. The effect is impressive, even for city dwellers who have never seen a marsh: every two miles of wetlands south of New Orleans reduces tropical storm surges there by half a foot.³² Louisiana's coastal wetlands and barrier islands also help shield an internationally significant commercial-industrial complex from the destructive forces of storm-driven waves and tides.³³

²² Michael Grunwald & Susan B. Glasser, Experts Say Faulty Levees Caused Much of Flooding, WASH. POST, September 21, 2005, at A1.

²³ Remarks by Ivor van Heerden, Deputy Director of Louisiana State University Hurricane Center, at Annual Conference of Louisiana Environmental Action Network, Baton Rouge, LA (Nov. 12, 2005) (notes on file with the author).

²⁴ Id.

²⁵ Christopher Drew, Inquiry to Seek Cause of Levee Failure, N.Y. TIMES, Nov. 9, 2005.

²⁶ Brett Martell, Prosecutor to Follow up on Tips of Corruption in Levee-Building, PHIL. INQUIRER, Nov. 11, 2005 (from Associated Press).

²⁷ Drew, *supra*.

²⁸ See Drew, *supra*, Martell, *supra*.

²⁹ Twenty-five percent of the Nation's coastal wetlands reside in southern Louisiana. MIKE TIDWELL, BAYOU BLUES: THE RICH LIFE AND TRAGIC DEATH OF LOUISIANA'S CAJUN COAST 6 (2003).

³⁰ U.S. ARMY CORPS OF ENGRS, 1 LOUISIANA COASTAL AREA (LCA), LOUISIANA: ECOSYSTEM RESTORATION STUDY, FINAL §1.1 (Nov. 2004), available at <http://www.lca.gov/final/main—report1.aspx>.

³¹ Id.

³² Sydney Blumenthal, No One Can Say They Didn't See It Coming, SALON, Aug. 31, 2005, available at <http://www.salon.com/opinion/blumenthal/2005/08/31/disaster—preparation/> (last visited September 21, 2005).

³³ U.S. ARMY CORPS OF ENGRS, *supra* note 2, at §1.1. A complex of deep-draft ports, including the Port of South Louisiana, handles more tonnage than any other port in the Nation. Id. Five years ago, "Louisiana led the Nation with production of 592 million barrels of oil and condensate (including the outer continental shelf), valued at \$17 billion, and was second in the Nation in natural gas production with \$1.3 billion (excluding the outer continental shelf)." Id. In addition, more than 29 percent of the country's crude oil supply and nearly 34 percent of

In addition to storm protection services, the Louisiana coastal plain also provides numerous other benefits. It offers habitat for countless species, including commercially significant sea life and waterfowl.³⁴ With more than five million birds wintering in Louisiana, the Louisiana coastal plain provides crucial rest stops to migrating birds.³⁵ Finally, Louisiana's coastal marshes provide services vital to water quality. The marshes function as giant "water treatment plants," filtering out vast quantities of nitrogen, phosphorous, and other pollutants from incoming water bodies.³⁶ Taken together, the many services of Louisiana's coastal wetlands make them a treasure every bit as unique and breathtaking as the city of New Orleans itself. The coast's storm protection, habitat, and water treatment services, while impossible to precisely quantify, surely amount to billions of dollars of commercial benefit per year.³⁷

2. *The Failures of Wetlands Law and Policy*

Unbelievably, this giant of all coastal wetlands, this biotic and commercial treasure, is disappearing before our very eyes. Since the 1930s Louisiana has lost more than 1.2 million acres of coastal wetlands.³⁸ Before Katrina, the Corps has estimated that Louisiana was losing about 6,600 acres per year, a rate that if unchecked would result in a net loss of 328,000 acres—or an area roughly the size of Rhode Island—by 2050.³⁹

Why is this happening? The effect is partly due to natural subsidence: the soft soils of the coastal plain naturally shift and sink over time.⁴⁰ But this phenomenon, at best, explains only a small fraction of the loss.⁴¹ The real culprits are human-made: Louisiana's vast network of levees, navigational channels, and oil-and-gas infrastructure. While all of these things are important to safety and commerce, their significant effects on Louisiana's wetlands require intense study, mitigation, and remediation.

The levee system accelerates coastal land loss by reducing the natural flow of a river's freshwater and sediment to wetland areas where lost land would then naturally be replenished.⁴² Instead, that valuable water and sediment is funneled down the Mississippi and shot into the Gulf, toward the outer continental shelf, where the formation of barrier islands is impossible.

Louisiana's coastal plain is crisscrossed with a vast matrix of navigational canals, including 10 major navigational channels⁴³ and literally thousands of smaller access canals serving navigation, allowing oil rig access, and cradling oil and gas pipelines.⁴⁴ This network severely disrupts the natural flow of water and nutrients in wetland areas, isolating and starving them.⁴⁵ The major navigational channels pose their own special threat to flood control by sometimes acting as "hurricane highways," allowing storms to sweep inland, past marshland, like liquid bulldozers.

its natural gas supply moves through Louisiana, which, incidentally, also hosts about half of the nation's refining capacity. *Id.* This relationship helps explain the dramatic surges in fuel prices that immediately followed Katrina.

³⁴ Fisheries in the Gulf of Mexico provide about 20 percent of all seafood consumed in the United States. Nearly all of that catch is dependent, in some way, on the universe of microscopic plant and animal life first nurtured in the Louisiana Coastal Plain. Oliver A. Houck, *Land Loss in Coastal Louisiana: Causes, Consequences, and Remedies*, 58 TUL. L. REV. 3, 84–86 (1983).

³⁵ About 70 percent of all birds that migrate through the United States use the Mississippi and Central flyways. U.S. ARMY CORPS OF ENG'RS, *supra* note 2, at §1.1. The coastal plain also supports several endangered or previously endangered species, including bald eagles, brown pelicans, alligators, and various kinds of whales. Houck, *supra* note 6, at 90. The birdlife moving through southern Louisiana supports significant commercial enterprises, including tourism, birding, and hunting. Houck, *supra* note 6, at 88–90.

³⁶ *Id.* at 78–79. The marshes' natural store of fresh water also acts as a bulwark against intruding salt water, which, were it allowed to flow uninhibited up the bayous, would destroy crucial shellfish habitat and poison groundwater supplies south of New Orleans. *Id.* at 80–81.

³⁷ *Id.* at 99 (estimating an annual value of around \$10 billion in 1983, using two different valuation methods).

³⁸ U.S. ARMY CORPS OF ENG'RS, *supra* note 2, at iii. In the 1970s, Louisiana was losing an estimated 25,200 acres per year from a combination of natural and human process. *Id.* From 1990 to 2000, the rate slowed to 15,300 acres per year. *Id.*

³⁹ *Id.* That loss would represent 10 percent of Louisiana's remaining coastal plain. *Id.*

⁴⁰ *Id.* §2.1.1.4.

⁴¹ Houck, *supra*, at 15.

⁴² U.S. ARMY CORPS OF ENG'RS, *supra* note 2, §2.1.1.4.

⁴³ *Id.* §2.1.2.2.

⁴⁴ Hydraulic forces erode the banks of such canals, causing them to widen at sometimes alarming rates. The surface area of the coast's artificial waterways may, itself, account for "2 to 4 percent of [the coast's] total land mass." Houck, *supra*, at 37.

⁴⁵ *Id.* at 39–40.

In the 1980s, prompted by scientific studies documenting Louisiana's land loss, local groups made up of environmentalists, shrimpers, scientists, and business people began pushing for plans to save what would later be called "America's Wetland."⁴⁶ One result of such efforts was the Federal Coastal Wetlands Planning, Protection and Restoration Act of 1990 (the "Breaux Act"), which created a Federal and State task force to implement wetlands restoration projects with annual funds of around \$40 million.⁴⁷ Although the projects saved hundreds of acres of wetlands, advocates soon realized that a \$40 million program was insufficient. A much more ambitious plan was needed if the coast would ever be saved.

In 1998, state and Federal Agencies, with the participation of a diverse group of local churches, scientists, environmentalists, and fishermen, developed a book length plan called "Coast 2050: Toward a Sustainable Coastal Louisiana," which offered a host of ecosystem restoration strategies.⁴⁸ The underlying principles of the Coast 2050 Plan were to restore or mimic the natural processes that built and maintained coastal Louisiana. The complete plan, to be implemented over the next 50 years carried a price tag of \$14 billion, more than twice as much as the Everglades restoration project (nearly \$8 billion) and about the same as Boston's new underground highway, "The Big Dig." Though expensive, Coast 2050 actually seemed a bargain, considering the costs of doing nothing threatened to exceed \$100 billion in lost jobs, lost infrastructure, lost fishing, and increased hurricane damage.⁴⁹

But Coast 2050 was never funded. In 2004, hamstrung by climbing deficits, the White House demanded, under pressure from the Office of Management and Budget and the Council for Environmental Quality, that the Corps lower its sights and propose a scaled-down 10-year plan that focused only on a few projects that would cost between \$1 to \$2 billion.⁵⁰ That proposed plan, which would take 10 years and cost an estimated \$1.9 billion, is now known as the Louisiana Coastal Area (LCA) plan.

Still, state officials had hopes of securing more funds to restore the wetlands' storm-shielding capabilities. Louisiana Governor Kathleen Blanco pleaded with the Federal Government to grant her state "just a fraction" of the \$5 billion it annually received from oil and gases leases on the outer continental shelf off of Louisiana's coast.⁵¹ Louisiana, of course, never received a greater share of oil and gas royalties for wetlands protection. Indeed, it has not yet receive the anticipated \$1 to \$2 billion. The President's 2005 Energy bill provided only \$540 million for Louisiana's coastal restoration over 4 years.⁵²

This month a report by the National Research Council (NRC) of the National Academy of Sciences reviewed the LCA plan and recommended its approval, although it cautioned that the proposed plan was, alone, insufficient to address the full scope of erosion concerns.⁵³ The NRC report also recommended that the Corps consider more comprehensive, long-term plans, perhaps 20–30 years in duration.⁵⁴ Perhaps most importantly, the report emphasized the point that wetlands restoration projects be planned in conjunction with levee projects and land use planning.⁵⁵

D. Lessons and Recommendations

What should we learn from these events? With the help of experts across the country now studying the issues, a few lessons become apparent. I list these lessons below, each accompanied by a recommendation.

1. *Focusing only on levees is a fool's gamble. Any new hurricane protection vision must be integrated and must consider simultaneously levee and gate construction,*

⁴⁶ See TIDWELL, *supra*, at 131–32.

⁴⁷ The projects included restoring wetlands near New Orleans with mechanical pumps, shoring up the eroding coast of Cameron Parish, and revitalizing beaches on select barrier islands. *Id.* at 132–33.

⁴⁸ TIDWELL, *supra*, at 134.

⁴⁹ *Id.* at 134.

⁵⁰ Mark Schleifstein, Corps Seeks Help to Scale Down Plan, TIMES-PICAYUNE (New Orleans), Apr. 10, 2004. Money was not the only thing siphoned off from Louisiana's coastal restoration efforts. In the spring of 2004, New Orleans's Times-Picayune reported that Army Corps officials involved in restoring Louisiana's wetlands had "been sent to assist those fighting in and rebuilding Iraq, including oversight of a similar wetlands restoration project there" at the mouth of the Tigris and Euphrates River. *Id.*

⁵¹ Kathleen Babineaux Blanco, Saving America's Wetland, WASH. POST, Dec. 8, 2004, at A31 (op-ed).

⁵² Michael Scherer, Bush Fought Funding in Energy Bill for Gulf Coast Protection, SALON, September 1, 2005 available at http://www.salon.com/news/feature/2005/09/01/against_funding/ (last visited September 21, 2005).

⁵³ Mark Schleifstein, Report Gives Nod to Plan for Coast, NEW ORLEANS TIMES-PICAYUNE, Nov. 10, 2005.

⁵⁴ *Id.*

⁵⁵ *Id.*

wetlands restoration, habitat preservation, canal navigation, and patterns of residential and commercial development.—Levees don't protect people, flood protection systems do. Those systems are made of multiple layers of defense all working together—some natural, some enhanced by human engineering, and some completely artificial. Moving from the Gulf toward the land, South Louisiana's system begins with the outer continental shelf (which cuts surge dramatically), sand bars and barrier islands, marshes, cypress swamps, and finally levees (and, perhaps one day, surge barriers). Canal placement protects or destroys the integrity of those barriers. Residential and commercial development in threatened areas control the risk of disaster. A levee system, without these other layers of protection, could never protect New Orleans from the ravages of a Category 5 storm. And engineers designing levees cannot predict the burdens on their structures without being able to predict (and thus control) the integrity of the outer lines of defense.

The Dutch, who have revolutionized flood control, recognized years ago that a levee strategy, by itself, cannot protect a sinking city. Thus they have learned to design systems of flood control that are consistent with the natural features of the land, using islands, lakes, grassy plains, dikes, gates, and smart development policy to protect residents and commercial infrastructure.⁵⁶ The NRC report, based on expert science, agrees.

Looking at hurricane protection in an integrated way will not only save lives, but will save money, by allowing designers to choose lines of defense that make the most sense and that are cost-effective.

2. *Strong plans are adaptive plans. A new hurricane protection vision should incorporate a formal mechanism by which an independent, scientific board regularly assesses the design, condition, and performance of hurricane protection features (from levees to barrier islands) to call attention to areas in need of maintenance or improvement.*—Such a scientific board might be patterned after the Environmental Protection Agency's Scientific Advisory Board. The goal would be to create a means of regular independent, scientific review of hurricane protection features and requiring the Corps to respond to such reviews. Such a review board could be made part of the independent hurricane protection commission offered later in Recommendation 4.

3. *What's good for the environment is good for hurricane protection. A new hurricane protection vision must adhere to current environmental and procedural standards, including the National Environmental Policy Act (NEPA).*—An effective hurricane protection strategy must rely on the health and effectiveness of natural features like marshes, swamps, and barrier islands. Laws like NEPA and the Clean Water Act's wetlands protection program, when followed faithfully, help to protect natural resources and their important ecological services. The procedural standards in such laws insure public notification and involvement, while making sure that large and expensive proposals are debated and thought through upon before being enacted.

4. *The Corps can't do it alone. Effective hurricane protection in the Gulf may require the establishment of an independent commission made up of Federal, State, and local officials, with expertise in policy, land use, science, and engineering to supervise the work of the Corps and other governmental and private entities whose work relates to hurricane protection.*—There are three main reasons for an independent commission. First, an integrated approach to hurricane protection will involve areas of expertise outside primary Corps functions, such as land-use planning. Second, such a large, ongoing project probably requires the full attention of a single organization whose sole function is to monitor its effectiveness. Third, the Corps is likely to be seriously distracted by ongoing civil and criminal investigations that are likely to result in lawsuits. These events will make it difficult for the Corps to be open and forthcoming with its own levee assessments, particularly if they find faults in the Corps's implementation. Whatever the results of such lawsuits or investigations, the Corps will have lost public credibility. An independent commission could bring needed direction and credibility to flood protection efforts.

Thank you for the opportunity to appear before your committee today.

RESPONSE BY ROBERT R.M. VERCHICK TO AN ADDITIONAL QUESTION FROM
SENATOR INHOFE

Question. When answering Senator Jeffords question at the hearing you reference GAO testimony given before the House of Representatives as further proof that the

⁵⁶ See John McQuaid, *Beating Back the Sea: How the Dutch Fight to Save their Low-Lying Land*, NEW ORLEANS TIMES-PICAYUNE, Nov. 14, 2005, at A1.

Barrier Plan “would not have helped, and probably caused more damage.” Are you aware that before you referenced this GAO testimony, GAO had already gone back and retracted its own testimony?

Response. My statement about the barrier project was based on two opinions one from Ivor van Heerden, Deputy Director of Louisiana State University Hurricane Center, the other from Anu Mittal, GAO’s Director for Natural Resources and Environment.

You ask if I was aware that Ms. Mittal has retracted her opinion. I am not aware of such a retraction. On September 28, 2005, Ms. Mittal testified before the Subcommittee on Energy and Water Development of the House Appropriations Committee on the subject of the original barrier plan. She stated: “In fact, Corps staff believe that flooding would have been worse if the original proposed design had been built because the storm surge would likely have gone over the top of the barrier and floodgates, flooded Lake Pontchartrain, and gone over the original lower levees planned for the lakefront area as part of the barrier plan.” On November 9, 2005 eight days before my testimony—Ms. Mittal testified before your Committee on the same subject with substantially similar testimony. Unlike her testimony of September 28, 2005, Ms. Mittal’s prepared testimony before your Committee did not state an opinion about what would have happened had the barrier project been in place at the time of Hurricane Katrina. But she did not retract the former statement in her written testimony. If Ms. Mittal or another GAO official has retracted the statement, it has not been reported widely in the press. My electronic searches through news stories after her House testimony reveal no mention of such a retraction, though Ms. Mittal’s original statement on September 28, 2005, was reported. In addition, I understand that Ivor van Heerden continues to stand by his opinion.

RESPONSES BY ROBERT R.M. VERCHICK TO ADDITIONAL QUESTIONS FROM
SENATOR JEFFORDS

Question 1. In your testimony, you note that land use planning is a critical part of the redevelopment process, but outside of the normal area of expertise for the Corps. Can you articulate how you believe land use planning can be used to drive federal investment, possibly reducing the cost of hurricane protection, and how much progress you think the state and local governments are making in producing a comprehensive redevelopment plan?

Response. It is critical that the Federal Government incorporate land-use planning into its levee and coastal restoration projects. Such planning would allow the government to protect natural hurricane barriers and flood plains, give the developers fair warning of what is off limits, and insulate necessary protection projects from local opposition. The authority to designate future land-use for purposes of storm protection and coastal restoration, including the development of planning maps, could be shared by the Army Corps (or a supervisory body) and the state. The Lake Pontchartrain Basin Foundation is developing such a map for advisory purposes. Still, the Corps has not been given explicit authority by Congress to follow such a map or to develop its own.

Question 2. In your testimony, you describe the need for adaptive management. In the Water Resource Development Act of 2000, Congress enacted the first authorization for adaptive management with an authorization of 10 million dollars. Is this the type of action you would like to see us take in response to Katrina specifically authorizing the Corps to spend money just for the purpose of continuously reviewing and revising its hurricane protection plans?

Response. Reviewing and revising its hurricane protection plans are the most important things it should be doing. Had the Corps had its requested budget and had it the authority to spend resources “just for” that purpose, the disaster in New Orleans might never have happened. Barrier islands change. Coastal wetlands change. Sea levels rise. Land sinks. If our protection projects do not adjust with these changes, we are fostering a false sense of security and wasting our money.

Question 3. Did the barrier plan under consideration by the Corps of Engineers in the early 1970s include features that may have reduced the storm surge that entered the city through the MRGO Canal?

Response. I am not aware of any feature of the barrier plan that would have reduced the storm surge that entered the city through the MRGO.

Question 4. With regard to the 1977 district court ruling by Judge Schwartz in the “Save our Wetlands” *v. Rush* case, how and why did the Corps decide not to pursue the barrier option to protect Lake Pontchartrain from coastal surges rising from the Gulf?

Response. The Corps was encountering strong opposition to the barrier plan from local citizens who did not want to pay a very high price for a project that might endanger the vitality of Lake Pontchartrain and from representatives of areas on the Lake Borgne side of the barrier who would have been at greater risk of flooding during hurricanes. By 1982, the New Orleans district of the Corps of Engineers had changed its mind and favored the high level plan "because it would cost less than the barrier plan" and "have fewer detrimental effects on Lake Pontchartrain's environment." One of the factors underlying the changed cost assessment was no doubt the escalating cost of acquiring rights of way from property owners who opposed the barrier project.

Question 5. It is worth noting that the barrier plan experienced significant local opposition at the time, documented in part by an informal poll conducted by Congressman Livingston, which showed that 62 percent of New Orleans residents either opposed the barrier or wanted to wait to construct it until studies were completed. Can you describe your understanding of the reasons the Corps abandoned the barrier plan?

Response. Please see answer to previous question.

Question 6. Mr. Verchick, in the opinion of the lawsuit in question, the judge wrote, "The foregoing opinion should in no way be construed as precluding the Lake Pontchartrain project as proposed or reflecting on its advisability in any manner. The Court's opinion is limited strictly to the finding that the EIS of August 1974 for this project was legally inadequate. Upon proper compliance with the law with regard to the impact statement this injunction will be dissolved and any hurricane plan thus properly presented will be allowed to proceed." Can you comment on whether or not this finding precluded the Corps from proceeding with the barrier plan?

Response. This ruling did not preclude the Corps from proceeding with the barrier plan. It merely required the Corps to produce an adequate Environmental Impact Statement before doing so. In the 1970s the Army Corps often encountered challenges to its EISs. It regularly returned with improved EISs and proceeded with its projects in substantially original form.

Question 7. One of the items in question in the EIS for the barrier project was the fact that the biological analysis in the EIS relied only on one phone conversation with a single marine biologist. Another item in question was that the benefits assessment included the benefits of destroying wetlands for urban development but failed to consider that the area had been designated as a protected wetland. Can you comment on what these points demonstrate about the NEPA process and its application to the barrier project?

Response. NEPA is a "stop and think" provision. It requires the federal government to stop and think about large projects before embarking upon them. The NEPA process helps government identify ecological issues as well as economic issues. In the case of the barrier project considered at a time when NEPA was relatively new the Corps's EIS was woefully inadequate. In reconsidering the proposal, the Corps saw both ecological and economic challenges to the proposal. It then chose another option the levee option which it believed would be more efficient. Indeed, that option would have protected New Orleans from most of Katrina's devastation had it been designed and constructed properly. It is the Corps's failure to properly design and construct the levees that apparently resulted in the flooding of most of the city. The NEPA process had nothing to do with that failure.

RESPONSES BY ROBERT R.M. VERCHICK TO ADDITIONAL QUESTIONS FROM
SENATOR VITTER

Question 1. You suggest that our hurricane protection system must have "adaptive plans". Are you familiar with the current Corps authorization process? Do you believe that this system provides the adaptive structure needed?

Response. It clearly does not. The Corps needs an explicit mandate and a budget earmarked for such review and maintenance.

Question 2. You stated that "what is good for the environment is good for hurricane protection". Could you expand upon this statement?

Response. Protecting and restoring coastal wetlands and barrier islands is good for the environment. These natural systems are necessary to buffering storms and slowing storm surges. Protecting and restoring coastal wetlands is good for, and indeed necessary for, hurricane protection in the region. In addition, what is good for the environment and for hurricane protection is also good for the economy, as these

natural features are necessary to support the Gulf fisheries and to protect oil and gas infrastructure in the Gulf.

Question 3. Would you support a streamlined environmental process that would allow for an expedited NEPA approval process to insure a greater level of hurricane and flood protection at a faster pace?

Response. Absolutely not. First, there is no evidence that the NEPA process is slowing the building of hurricane protection. If anything is slowing this process, it is the reluctance of the White House and Congress to support Category 5 protection. Second, the NEPA process serves the goal of hurricane protection by encouraging the government to consider environmental effects in its analysis. Recall that protection of the coastal environment (islands, wetlands, and the surrounding ecosystems) enhances storm protection. Everyone wants levees built as fast as possible, but not if they will be done poorly. If anything, Katrina should teach us to “measure twice, cut once.”

Question 4. Currently, the section 404 program does not distinguish between coastal wetlands subject to erosion and inland wetlands. I have heard from numerous constituents about the barriers they have encountered when trying to protect coastal wetlands from loss. Knowing the importance of coastal wetlands to buffer storm surge, do you believe we should revisit this policy?

Response. I am not sure how this lack of distinction impedes the protection of coastal wetlands. I would need more information to answer the question.

Question 5. The levees installed on the lower Mississippi River system and the construction of the MRGO have caused the loss of hundreds of thousands of acres of wetlands subject to section 404 jurisdiction. In many cases, these same coastal wetlands are also designated “critical habitat” for endangered species. Do you believe we should hold the federal government responsible for these actions?

Response. Yes.

Question 6. Louisiana currently has only three miles of state waters. Texas and Florida have over nine miles of coastal waters. This disparity has caused Louisiana to lose billions of dollars in offshore energy royalties. These funds could have been used to restore our coast and provide hurricane protection. What are your thoughts on this unequal treatment?

Response. The treatment is unfair to Louisiana and unwise for the country. It is unfair in the context of other Gulf states, but also in the context of royalties for other minerals. Interior states, for instance, receive much greater benefit from the royalties of minerals mined on their land than does Louisiana from oil and gas. It is also unfair in the sense that Louisiana’s coastal erosion (and thus its increased exposure to storm surges) is in large part caused by the oil and gas industry. At the very least, Louisiana should be compensated for these externalities. Louisiana’s claim to more oil and gas revenue goes beyond a claim for royalties, it is a claim for restitution for the despoilment of its coast and the increased threat to its people. These externalities are not visited upon Texas and Florida (which have fewer protective wetlands), even though they receive more revenue. It is an unwise policy for the country because the oil and gas infrastructure relies on the protection from storm surges.

Question 7. In your testimony, you call for an independent commission to “supervise” the work of the Army Corps. Could you provide another example where this model has been successful?

Response. Two different models are the South Florida Ecosystem Restoration Task Force and the Tennessee Valley Authority. The systems are far from perfect, particularly in the latter case. But the idea of a supervisory commission with broad expertise would benefit the rebuilding of the Gulf Coast.